Endangered Ecosystems

A Status Report on America's Vanishing Habitat and Wildlife

By Reed F. Noss and
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DEFENDERS OF WILDLIFE

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ABOUT DEFENDERS OF WILDLIFE

Defenders of Wildlife is a leading nonprofit conservation organization recognized as one of the nation's most progressive advocates for wildlife and its habitat. Defenders uses education, litigation, research and promotion of conservation policies to protect wild animals and plants in their natural communities. Known for its effective leadership on endangered species issues, particularly predators, Defenders also advocates new approaches to wildlife conservation that protect species before they become endangered. Its results-oriented programs reflect the conviction that saving the diversity of our planet's life requires protecting entire ecosystems and ensuring interconnected habitats.

Founded in 1947, Defenders of Wildlife is a 501(c)(3) membership organization with more than 120,000 members and supporters. Headquartered in Washington, D.C., Defenders maintains a staff of wildlife biologists, attorneys, educators, research analysts and other conservationists.

COVER PHOTO: George Wuerthner/Mahogany Hammock in Everglades National Park

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Foreword

Defenders of Wildlife started work on this report two years ago because we were concerned about the lack of public attention and policy initiatives on the problem of disappearing ecosystems. Although the problem has received increasing recognition from scientists, the public remains largely unaware that we are losing immense portions of America's natural habitat resulting in an accelerating loss of species. With this report, we hope to educate the public and policymakers about this newly identified emergency so that steps will be taken to ensure that future generations can fully enjoy our natural heritage.

When the first national parks were established in the late 1800s at the urging of John Muir and other farsighted conservationists, the expectation was that the park system would preserve in perpetuity large expanses of habitat which even then were being rapidly replaced by farms and cities. An 1885 congressional commission on Yellowstone National Park argued for sparing Yellowstone's "display of wonderful forms of nature" from the "vandalism of improvement[1]." During the 20th century, as U.S. population and consumption of natural resources grew rapidly, it became clear that national parks and other protected public lands such as wilderness areas and wildlife refuges would not be sufficient to provide safe harbor for all the nation's species. This realization — that encroaching civilization was leaving many species without habitat necessary to survive — led to the enactment in 1973 of the Endangered Species Act, the world's most progressive biodiversity law.

Defenders of Wildlife has championed the Endangered Species Act since its inception. (We recently published "Saving America's Wildlife: Renewing the Endangered Species Act", our fourth comprehensive guide to the act for policymakers and the public.) But an honest appraisal of the state of the nation's wild lands forces us to conclude that the Endangered Species Act alone is not enough to halt either the extinction of species or the loss of ecosystems on which they depend. This report shows that natural ecosystems — unique communities of interdependent plants and animals — are being destroyed nationwide, victims of excessive logging, livestock grazing, agricultural development, fire exclusion and residential sprawl. When these ecosystems vanish, so do hundreds of species that depend on them for habitat — the dwindling southern California coastal sage ecosystem alone contains 74 species that have been federally listed or proposed for listing as threatened or endangered, or are candidates for listing.

We are sounding the alarm to help motivate the public and policy makers to help solve this problem. Ecosystem destruction is not an arcane topic but something that directly affects us all. Does anyone really want to live in a world where monotony reigns, where the wildlife in our backyards and national parks is limited to pigeons, deer and squirrels? Does anyone want to pay the billions of dollars it would cost, for example, to use artificial fertilizers and water-treatment plants instead of depending on the natural ecological processes that provide us with fertile soils and clean water?

What should be done? Unfortunately, members of the 104th Congress are headed in the wrong direction. They have moved to increase logging on national forests, including the Tongass National Forest in Alaska, allow oil drilling on the Arctic National Wildlife Refuge's coastal plain and dismantle the Endangered Species Act. What this report shows is an urgent need to strengthen laws and policies that protect the environment, not weaken them.

Specifically, we recommend that saving ecosystems be made a national goal. Achieving this goal will mean adequately funding ecosystem conservation, giving it highest priority in decisions about how we use our public lands, improving the scientific base on which these decisions are made, developing innovative approaches to land management that focus on entire ecosystems (both public and private land) and reforming government policies that undermine conservation.

We are convinced that the loss of natural ecosystems, which threatens to diminish the quality of life nationwide, should be of the highest significance. We are particularly concerned with the 21 most-endangered ecosystems identified in this report. We call upon federal, state and local governments and the American people to reverse the trend of ecosystem destruction and realize that we can and must learn to live in harmony with nature.

Rodger Schlickeisen
President, Defenders of Wildlife

Executive Summary

Since the time of European colonization, millions of acres of North America's natural ecosystems have been destroyed, degraded and replaced by agriculture and concrete. Iowa's tallgrass prairies, once habitat for wolves and buffalo, are now fields of corn. California's golden bear, a subspecies of grizzly, can now be found only on the state flag. The native wildflowers and bunchgrasses of California have dwindled and the hills are now covered with wild wheat, thistles and mustard from Europe and Asia. The entire south Florida landscape, including the Everglades and pine rockland habitat for endangered Key deer, is so seriously degraded that we have identified this entire area as the most endangered ecosystem in the nation.

The magnitude of decline is staggering. For example, the nation has lost 117 million acres of wetlands — more than 50 percent of what was here when Europeans arrived; the Northwest has lost 25 million acres — 90 percent — of its ancient forest; California alone has lost 22 million acres of native grasslands. What little untouched natural landscape remains is becoming increasingly fragmented. Our national forests alone contain nearly 360,000 miles of roads, more than eight times as much as the Interstate Highway System. In the West, 270 million acres of public rangeland are affected by livestock grazing — nine of every ten acres. Although some loss of ecosystems is an unavoidable price of development, the destruction has advanced far beyond what is necessary, because of poor planning, emphasis on short-term economic gain and misplaced government priorities.

The ultimate driving force behind this degradation is America's population, which is growing by 2.6 million every year, equivalent to a city the size of Chicago. Total U.S. population grew nearly 10 percent between1982 and 1992, with some states like Florida and Nevada growing by more than 25 percent (Table 11, page 128). All these people require living space, clean water to drink, farms to supply their food and timber to build their houses. Because Americans consume so much more energy, food and raw materials than the average global citizen, their impact on natural ecosystems is immense. The result is that wild America has been pushed to the wall.

Throughout the nation, ecosystem destruction is increasing. "Reclamation" of wetlands for agriculture continues in the midwestern states. New congressional initiatives would accelerate destruction of wetlands, which are essential breeding habitat for waterfowl. Livestock grazing on damaged western lands continues. Logging in the Pacific Northwest and Alaska is eliminating what little old-growth forest remains, including ancient redwood ecosystems. Residential development in California and other western states is destroying grasslands, chaparral and vernal pools, home to fairy shrimp and other endangered species. Along the coasts, America's continuing love affair with living near the sea drives a building boom that is making hundreds of additional species candidates for federal protection.

What will the future be like if these trends continue? Without dramatic changes in our patterns of land and resource use, more ecosystems will become fragmented and degraded or disappear along with the wildlife they support. The remaining wild lands will be replaced by vast stretches of residential sprawl, factory farms, and tree plantations. In southern California, most of the natural ecosystems along the coast have already been converted to housing and developers are hungrily eyeing Camp Pendleton Marine Corps Base, the largest remnant of coastal green space. Because Florida is so developed, the Florida panther and the state's subspecies of black bear have been pushed into areas so small that a predominant cause of mortality is motor vehicle collisions. Both animals could disappear if new roads like the proposed State Road 40 and widening of U.S. 19 are allowed to chop up remaining habitat. In the Southwest, all riparian ecosystems are under extreme pressure. Some rivers, such as the lower Gila in Arizona, have been largely pumped dry and the native riparian ecosystems have been destroyed. As western states continue to grow, the demand for water will increase, putting the Gila, Colorado and other rivers at still greater risk.

Overview of Findings

Our study emphasizes that extensive habitat destruction is reaching the point where the nation faces the loss of hundreds of natural ecosystems, including California's ancient redwood forests, longleaf pine forests in the Southeast, beach dune habitats along the East Coast, and even subterranean communities of blind fish and crustaceans in Tennessee caves. Used in this sense, the term "ecosystem" means a characteristic community of interdependent plants, animals and microorganisms associated with particular kinds of soil, temperature, rainfall and disturbance patterns. Thus, the redwood ecosystem can be found in patches throughout northern California wherever soil, weather and fire frequency are suitable.

Of the hundreds of imperiled ecosystems, this report identifies the 21 most-endangered ecosystems based on four factors (See Table 4, page 116). Ecosystems rank high on Defenders of Wildlife's risk scale if they have been greatly reduced since Europeans settled North America, if they are now very small, if they have many imperiled species, and/or if the continued threat to their existence is high. For example, southern California coastal sage scrub ranks high — in the top ten — because it has been much reduced by development, because it harbors many endangered species and because bulldozers are steadily chewing up what remains. Other most-endangered ecosystems on our list are the south Florida landscape, longleaf pine forests and savannas (grassland with scattered trees), tallgrass prairie, Hawaiian dry forests, old-growth forests of the Pacific Northwest and midwestern wetlands. Note that although we identify these most-endangered ecosystems as having the greatest risk of disappearing, and they therefore deserve high priority for conservation, conservation organizations or agencies might give equal or greater priority to ecosystems not identified here. In order to set their priorities, conservation organizations need to consider not only risk of disappearance but also ecological importance, political and economic opportunities for conservation and other factors.

In acres lost to other land uses since European settlement, the most reduced ecosystems are prairies and other grasslands, savannas (for example, oak savannas in the Midwest) and some forests and wetlands. Table 1 (page 108) of our report lists 27 ecosystem types that have lost more than 98 percent of their original extent, including spruce-fir forest in the southern Appalachians, pine rockland habitat in south Florida, wet and mesic coastal prairies in Louisiana, sedge meadows in Wisconsin, and Palouse prairie in the Pacific Northwest.

In many ecosystems, what little remains has been largely degraded. Poorly managed grazing on western public lands has resulted in loss of native grasses and other plants and has contributed to the imperilment of at least 340 species that are listed as endangered or threatened or are candidates for listing.[2] Suppression of natural fires has caused gradual deterioration of fire-dependent terrestrial and wetland communities such as prairies, barrens, southern canebrakes and longleaf pine and ponderosa pine forests. Fire suppression in longleaf pine forests causes invasion by hardwood trees and a major change in the species composition of the forest.

Aquatic ecosystems have been severely degraded by dams, channelization and pollution. Between 90 and 98 percent of the nation's streams are in bad enough shape to be ineligible for federal designation as wild and scenic rivers, and more than 80 percent of the nation's fish communities are considered degraded because of decline or loss of native species and introduction of exotics. Of Arizona's 30 existing native freshwater fishes, all but one are either threatened, endangered or a candidate for listing under the Endangered Species Act. The Mobile River Basin in Alabama was once home to more than 30 mussels and 130 snails found nowhere else in the world. Today more than half the mussels and nearly a quarter of the snails are extinct.

Besides identifying which ecosystems are most endangered, Defenders determined which states are experiencing the greatest threats to their ecosystems and associated wildlife. States were ranked according to how many endangered ecosystems they contain, how many rare species they have and how much development is occurring. The ten states with the greatest overall risk of ecosystem loss are Florida, followed by California and Hawaii (tied), Georgia, North Carolina and Texas (tied), South Carolina and Virginia (tied), and finally Alabama and Tennessee (tied) (See maps, page xiv; Table 5, page 118).

Most of these states are experiencing rapid growth. In Florida, for example, the amount of developed land increased 35 percent in the decade from 1982 to 1992. If this rate of increase were to continue for the next 70 years, all developable land in the state, including agricultural land, would be covered by houses and concrete. While this is not likely to happen, this statistic illustrates the frantic, unsustainable pace of Florida's current growth. Our Development Threat Index shows that development pressures are greatest in the Southeast and Southwest and parts of the East Coast (See Map 6, page 22). States with the highest development scores are Florida and New Jersey (tied), Delaware and Maryland (tied), Massachusetts and Rhode Island (tied), and California, Connecticut, Georgia, North Carolina, New Hampshire, South Carolina and Virginia (tied).

Our study shows that all 50 states have serious problems, even those ranking relatively low in overall risk. Iowa, for example, falls in the bottom third of states based on overall risk to ecosystems, largely because it has low rates of population and development growth and relatively few large urban centers. Yet agriculture has gobbled up 95 percent of Iowa's original 40 million acres of forests, prairies and wetlands, and much of what remains is degraded. Seventy native Iowa plant and animal species have vanished from the state, including wild bison and black bear, wolf, cougar, elk, trumpeter swan, greater prairie chicken, sandhill crane, long-billed curlew and burrowing owl. Iowa lists more than 200 plants and animals as endangered or threatened.

Alaska, which falls at the bottom of Defenders' state rankings, nonetheless contains many ecosystems under duress, including the belt of ancient temperate rainforest stretching from the Kodiak Archipelago southeast along the Gulf of Alaska to the Alaska panhandle. This rainforest is one of the last refuges for many vulnerable species, among them the brown bear, Alexander Archipelago wolf, Queen Charlotte goshawk and marbled murrelet. Also at risk is the Arctic National Wildlife Refuge's coastal plain, where some members of Congress want to allow oil drilling. The plain is the calving ground of one of the continent's largest caribou herds.

Ironically, many states are steadily losing the very ecosystems that make them attractive places to live and to visit. Florida, Defenders' top state in terms of risk to ecosystems, draws new resi-

Risk to ecosystems map

dents and an immense number of tourists specifically because of the natural beauty of the coral reefs, the Everglades marshes and wildlife and the state's other natural ecosystems. Yet the impact of these people is enormous. More than half of Florida's wetlands have been lost to drainage and development, including more than 65 percent of the 3,900-square-mile Kissimmee-Okeechobee-Everglades system. Agriculture and development have interrupted vital water flow across the Everglades and loaded the water with phosphorus and nitrogen, stimulating the growth of dense stands of cattails that choke out sawgrass and other water bird habitat. The Everglades' wading-bird flocks, once estimated at more than 2.5 million birds, have declined by 90 percent since the last century. This unacceptable condition is recognized in a new report by the Commission on a Sustainable South Florida appointed by Governor J. Lawton Chiles that recommends redirecting growth away from the Everglades and other ecologically valuable places because tourism, drinking water and the fishing industry all depend on a healthy natural environment.

Why Care About Ecosystems?

As Governor Chiles's commission concluded, there are economic reasons to save ecosystems. In Florida and elsewhere, people pay handsomely to live and play in natural surroundings. They want to see natural forests with a full complement of birds, flowers, and other wild things, not species-poor plantations of genetically identical pine trees. In Hawaii, they want to see colorful native birds and flowers, not fields of grass and cattle.

Moreover, natural ecosystems provide people with what are known as ecosystem services, including building of fertile soil, purifying both the water and air, and providing flood control. Loss of these services has real although often hidden costs. For example, natural forests on mountain slopes can absorb twice as much water as do plantation forests, slowing runoff and erosion and preventing downstream flooding. Wetlands, estuaries and other aquatic systems provide free sewage treatment. The New York Bight, a 2,000-square-mile embayment at the mouth of the Hudson River, biologically treats the waste produced by 20 million people in the New York metropolitan area. If this biological filter is damaged by excessive pollution, as seems to be occurring, the cost of replacing these services with mechanical and chemical treatment facilities will run into billions of dollars.

Healthy ecosystems also are essential for species to survive. As ecosystems unravel, the species they sustain become candidates for the endangered list. Most of the 956 U.S. threatened and endangered plant and animal species and the 3,902 candidates for listing are in trouble because of habitat loss. Loss of perhaps 99 percent of Atlantic white cedar swamps has caused endangerment of the green Hessel's hairstreak butterfly, a species whose larvae can feed only on the cedar leaves. The imperiled buck moth of the northeastern states is dwindling along with the vanishing pine barrens. If habitat destruction continues, we can expect the number of threatened and endangered species to skyrocket. By waiting until ecosystems are so deteriorated that their component species are in danger of extinction, society incurs huge social and economic costs. This leads to conflict between those people eager to save our living heritage and developers and other exploitive interests.

What Must Be Done?

The challenge is to make our national endeavors less invasive, destructive and wasteful, so that there is room for both humans and nature. Curbing excessive human population growth and its consumption of resources should be a top priority, but even if we are not fully successful much can be done today to reduce the impacts of economic development on natural ecosystems and thereby improve the quality of life for us and our descendants. We can conserve, recycle and reuse natural resources such as wood products. We can restructure government subsidies to discourage methods of ranching, farming and logging that are environmentally destructive and promote those that are beneficial. We can pass zoning ordinances to slow sprawl and promote communities where neighbors live closer together. We can direct further development to lands that already have been ecologically degraded and away from the last unspoiled natural landscapes and we can restore those already degraded.

Making such fundamental changes will require help from government on all levels as well as from industry, developers, scientific institutions, philanthropic foundations, conservation organizations and individual citizens. Because most land-use decisions are made by local government, local efforts to protect natural lands can have tremendous cumulative impact. State and federal initiatives can focus on large-scale patterns of land and resource use, economic incentives and coordinated scientific programs.

It is imperative that the public and policymakers begin to take action. Defenders makes the following recommendations for conserving our nation's ecosystems:

• **Make ecosystem conservation a national goal.** All sectors of society must make ecosystem conservation a high priority. We must provide better education about the importance of ecosystems, provide more resources for their conservation, and provide adequate protective legislation. Natural ecosystem protection should be given first priority on the nation's public lands.

• **Maintain and strengthen existing environmental laws.** We must defeat current efforts in Congress to rollback existing environmental laws that promote ecosystem conservation, among them the National Forest Management Act, Clean Air Act, Clean Water Act, Tongass Timber Reform Act and Endangered Species Act. Congress should also look for opportunities to strengthen the ecosystem protection provisions of the National Forest Management Act, the enabling legislation of the National Wildlife Refuge System and other appropriate legislation.

• **Reform policies that harm ecosystems.** We should eliminate or reform government laws and subsidies that support harmful resource use, including those permitting hardrock mining and petroleum drilling in ecologically sensitive areas, old-growth timber sales, below-market fees for grazing on ecologically degraded or sensitive federal lands, and subsidies for agricultural commodities like corn and soybeans that encourage conversion of wetlands and hedgerows to crop production. As a supplement to traditional regulatory approaches, we should use economic incentives and other creative techniques to encourage landowners to manage their lands in ways that sustain natural ecosystems.

• **Improve scientific knowledge about ecosystems.** We must improve the knowledge base for making informed management decisions. A key need is a robust national scientific agency, such as the National Biological Service, that has the financial and technical capability to spearhead a national effort to map ecosystems, identify ecosystems at risk, organize ecological research and provide the scientific tools for proper conservation and management.

• **Develop appropriate management plans for whole ecosystems using "ecosystem management."** Planning and management should take place on large geographic scales that consider the needs of entire ecosystems, not just pieces. All public and private land managers with jurisdiction over an ecosystem should cooperate and base their joint plans on the best available conservation science, including consideration of disturbance regimes* and minimum viable popula-

* A disturbance regime is the specific type, size and frequency of disturbance that occurs in an ecosystem. In longleaf pine forests the historical disturbance regime was characterized by frequent, low intensity fires, covering large areas

tion sizes* for key species. Because ecosystems are so complex and in many cases exceed our ability to understand them completely, managers should use "adaptive management," meaning that managed ecosystems should be continuously monitored so that timely action can be taken to correct for faulty management or changing conditions.

Overview of Report Structure

Our report begins in Section 1 with a status review of the nation's ecosystems, identifying which ones are substantially reduced in area, rare, contain the most endangered species, and/or face the greatest threats from humans. A survey of threats is placed in Appendix A. We also present a list of the nation's 21 most-endangered ecosystems, case studies for which are in Appendix B. In Section 2 we present our assessment of how high the risk to ecosystems is in each state, and in Section 3 we present five state case studies — Florida, California, Hawaii, New York and Iowa. We chose states that represent different regions of the country, and we took a historical approach to illustrate how past land-use patterns have affected composition and distribution of ecosystems. Finally, we make recommendations for acquiring better information on the status of ecosystems and for protecting and restoring them.

* A minimum viable population size (MVP) is the minimum number of individuals necessary to ensure that a population survives over some specific period of time, given known causes of mortality, genetic characteristics, demographic makeup and other factors. MVPs generally considered necessary for long-term survival of large mammals are in the range of 500 to 1,000 individuals.

Introduction

If the natural world were dull and monotonous, perhaps we would not be so adamant about trying to save it. But it is far from boring. It is infinitely complex and inviting, filled with orchids and beetles, birds, forests and deserts. The sum of this life is called biodiversity.

As scientists now interpret it, biodiversity includes all the world's species, all the genetic variation they contain, and higher levels of biological organization — biological communities, ecosystems, landscapes and biomes*. Biodiversity is the foundation of human life, the ultimate source of food, fiber and other raw materials we use daily. It provides medicines to treat some of the most deadly diseases. It provides rich aesthetic experiences, spiritual renewal and opportunities for recreation and contemplation. Biodiversity, in the form of healthy ecosystems, cleans our water, purifies the air and builds soil, providing the life-support system for all living things.

But as indispensable as it is to human existence, biodiversity is is threatened. And it is threatened at every level of organization, from genes to species to biomes. Most people are familiar with threats to biodiversity at the species level; they know that some species are threatened with extinction. Although scientists are uncertain about the exact extinction rate, we know it is probably thousands of times greater than the rate prior to human civilization, and it is thousands of times the rate at which new species are evolving[3]. Concern about this depletion of the planet's and our nation's natural legacy persuaded Congress to enact what may be the strongest piece of conservation legislation in world history: the Endangered Species Act of 1973.

We Americans are justly proud of our Endangered Species Act. It has done much to acquaint people with the biodiversity crisis. Most schoolchildren, for example, can name several endangered or

* A biome is a continental- or subcontinental-scale region with distinctive vegetation and climate.

threatened species, such as the bald eagle, California condor or Florida panther. Polls show that most Americans prefer protecting endangered species over economic development when the two conflict. But although the Endangered Species Act has been moderately successful — it has certainly slowed the loss of species — it has failed to stem the overall tide of biotic impoverishment. Because it has usually been invoked at the eleventh hour, when recovery of species is difficult and expensive[4], many species have failed to recover even with its protection. It has been too little, too late.

Perhaps most significantly, the Endangered Species Act has failed to accomplish its first stated goal: "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved...." Not only species are threatened by human activities; entire U.S. ecosystems — longleaf pine forest, tallgrass prairie and other interacting communities of species — have been severely altered, and some are in danger of being erased from the face of the Earth. Recent studies show that few U.S. ecosystems are adequately protected in reserves or by other means[5]. Yet few Americans realize the size of the threat or how severely our native ecosystems have already been logged, plowed, grazed, bulldozed, paved, dammed, polluted and overrun by weedy invaders from other continents.

Ecosystems can be totally destroyed, as when a prairie is bulldozed for agriculture, or merely degraded as when fire suppression or high-grade logging changes the character of the vegetation (See Appendix A, page 45). Species may be lost, vital links between species severed or biological productivity decreased. The more an ecosystem is degraded, the more species decline or become extinct. Therefore, the inevitable consequence of ecosystem degradation is an ever-lengthening list of endangered species[6].

The reasons for saving natural ecosystems go far beyond saving individual species. Ecosystems provide what are known as ecosystem services, including recycling of water, creation of fertile soil, oxygenation of both the water and air, and an abundance of natural resources. Forests throughout the world work as giant carbon sinks, storing carbon dioxide and decreasing the greenhouse effect by which rising levels of carbon dioxide and other gases warm the earth. Loss of these services has real although often hidden costs. For example, forests on mountain slopes can catch twice as much water as do plantation forests, slowing runoff and erosion and preventing downstream flooding[7].

Wetlands, estuaries and other aquatic systems provide free sewage treatment. The New York Bight, a 2,000-square-mile embayment at the mouth of the Hudson River, biologically treats the waste produced by 20 million people in the New York metropolitan area[8]. If this biological filter is damaged by excessive pollution, as seems to be occurring, the cost of replacing these services with mechanical and chemical treatment facilities will run into billions of dollars. At a time when the political landscape is occupied by a struggle between those who see ecology as an obstruction to economic development and vice versa, it is essential that people understand that human well-being depends on the continued existence of a diversity of ecosystems and the preservation of as much as possible of the Earth's biological heritage.

This report is part of an effort by Defenders of Wildlife to help put conservation of ecosystems on the national agenda. We recognize that conserving natural ecosystems will save billions of dollars in ecosystem services and that the most efficient and cost-effective way to prevent species extinction is to protect intact ecosystems and, where possible, restore those already degraded. The nation needs to plan and act now to perpetuate healthy, sustainable ecosystems, rather than trying frantically to save each rare species at the last moment, when there are so few individuals left that protection becomes difficult and expensive. We therefore urgently need to supplement the "emergency room medicine" of the Endangered Species Act with a program to conserve ecosystems and thereby prevent more U.S. species from joining the endangered list.

SECTION ONE

Current Status of Ecosystems

What Are Ecosytems?

In this report we take ecosystem to mean a characteristic community of interdependent plants, animals and microorganisms associated with particular kinds of soil, temperature, rainfall and disturbance patterns.* Thus the redwood ecosystem can be found in patches throughout northern California wherever soil, weather and fire frequency are suitable. Other ecosystems discussed in this report include old-growth ponderosa pine forest, midwestern wetland, longleaf pine forest and tallgrass prairie. Our use of the term "ecosystem" should not be confused with another common use, which is to signify a geographic area functioning as an ecological unit, such as the "San Francisco Bay Ecosystem" or the "Greater Yellowstone Ecosystem."

Many of the ecosystem types we describe are roughly equivalent to what ecologists call plant communities or associations, along with their typical animals, soils and other components. Examples include red spruce forest and coastal sage scrub — these ecosystems are named after the dominant plants characteristic of the community. However, in this report we use a definition of ecosystem that is broad enough to include not only plant communities but also ecosystems defined on the basis of soil type, species composition, habitat structure, age, geography and condition. For example, one of the most endangered ecosystems is old-growth ponderosa pine forest of the West — a classification based on both vegetation type and age. Sandstone barrens are based on the type of substrate — sandstone. Caves, which typically lack green plants, are defined according to physical structure. Many of our ecosystem types are

* Although ecologists using different classification systems might disagree over how many distinct ecosystems there are, or over the boundaries between one type and another, most people have no trouble recognizing that it is useful to distinguish, for example, between a forest and a grassland. We recognize that scientists may also define ecosystems in terms of energy or nutrient flows and may define ecosystems on many scales, from the microscopic to the planetary.

defined in part by adjectives indicating condition, though these are not part of traditional plant community classifications. Examples include ungrazed semi-arid grasslands and free-flowing streams. We chose such a general definition of ecosystem because it allows us to assess loss or degradation of structural, functional or compositional aspects of ecosystems at any level of classification hierarchy and any spatial scale[9].

One important characteristic of these ecosystem types is that they can be measured and mapped. For example, we can map the remaining patches of the longleaf pine/wiregrass ecosystem, one of the largest examples of which is found in the Apalachicola National Forest in northwestern Florida. Just as we can evaluate the conservation status of individual species, so we can map and evaluate the status of ecosystems. We can identify which are rare and which have lost large portions of their historic range. We can conduct "gap" analyses to determine which ecosystems are well protected in conservation reserves and which are not*. We can identify specific threats to ecosystems, such as logging, roadbuilding, livestock grazing and suburban development —the same factors, in most cases, that threaten species. Given proper legal tools, we could designate endangered ecosystems in need of legal protection, just as we now list endangered species under the Endangered Species Act.

Which Ecosystems Have Lost the Most Area?

The National Biological Service (NBS)** study found that many types of ecosystems in the United States have already lost more than half of the area they occupied prior to European settlement. Some kinds of ecosystems are virtually gone, having declined by 98 percent or more (See Table 1, page 108). Many other types have declined by more than 85 percent, including old-growth forests in all states except Alaska, limestone cedar glades in the South and Midwest, wetlands of most types in the Midwest, Gulf Coast pitcher plant bogs, coastal redwood forests and vernal pools in California, riparian forests in the Southwest and California, dry forests in Hawaii and native beach communities and seagrass meadows in many coastal areas.

Aquatic communities have been severely degraded throughout the United States[10]. Although losses of aquatic biodiversity at the ecosystem level have been poorly reported, available data show that 81 percent of fish communities[11] nationwide have been affected adversely by human activities. Between 90 and 98 percent of streams nationwide are degraded enough to be unworthy

* A gap analysis is carried out by mapping the biodiversity elements we want to save, comparing this with a map of existing and proposed protected areas and observing where there are "gaps," i.e. important elements of biological diversity that are not adequately protected. For example, in the case of mammals, a gap analysis of the United States could map the ranges of all mammal species to ensure that all vulnerable species occur in at least some national parks or other protected areas.

** Much of our discussion in this section draws on data from the National Biological Service's (NBS) 1995 report entitled "Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation."

of federal designation as wild and scenic rivers[12]. In some regions, such as the Mississippi Alluvial Plain, virtually every stream has been channelized, leveed or otherwise altered[13]. The aridity of western lands means that there is relatively heavy impact on relatively few aquatic systems. In Arizona, for example, an estimated 90 percent of riparian habitat has been destroyed by dams, conversion to agricultural lands, water diversion projects, urban encroachment, cattle grazing and excessive ground water pumping[14]. Of Arizona's 30 existing native freshwater fishes, all but one are either extinct, listed as a federally threatened or endangered species or a listing candidate[15].

The loss of native ecosystems in the United States has been most severe in the Northeast, South, Midwest and California, but no region has escaped damage (See Figure 1, page 130). All kinds of natural communities have been affected. Although statistics on ecosystem decline suffer from reporting biases and inconsistencies in classifications (amazingly, no well-accepted national classification of ecosystems exists), some general trends are evident. Forests, wetlands, and grasslands, savannas and barrens dominate the list of ecosystems that have declined by 70 percent or more (See Figure 2A, page 131). However, if we look only at ecosystems that are extremely endangered — those that have declined by over 98 percent — they are primarily grasslands, savannas and barrens (See Figure 2B, page 131; Table 1, page 108). Grasslands have declined in most cases because they were easy to plow and convert to agriculture. Savannas and barrens, as well as many grasslands, became choked with colonizing trees and shrubs once people suppressed the fires that had kept the invaders out. Not surprisingly, many of the most endangered ecosystems are located at low elevations, typically near major rivers and coasts in areas with fertile soils, pleasant climate, level terrain, abundant natural resources and other factors that encouraged human settlement and exploitation.

Which Ecosystems Are the Rarest ?

So far, rare ecosystems have attracted most attention from conservationists. The Nature Conservancy (TNC), for example, has oriented its efforts mostly toward species and natural communities that are rarest, at either the state, national, or global scale. A recent report by The Nature Conservancy and the Natural Heritage Network describe some 371 globally rare terrestrial and wetland plant communities in the United States and lists another 482 communities known to be globally rare, but for which further research is required before they can be mapped and ranked with certainty*.

Table 2 (page 109) lists 130 plant communities identified by The Nature Conservancy and the Natural Heritage Network (Heritage\Conservancy) as rarest — "critically imperiled," according to their nomenclature. Most

* "Rare Plant Communities of the Conterminous United States: An Initial Survey," 1994. Grossman, D.H., K.L. Goodin, and C.L. Reuss. The Nature Conservancy, Washington, DC.

of these communities occur at fewer than five sites or on very few acres (usually under 2,000). Some of the types are severely restricted. For example, ponderosa pine/antelope bitterbrush/Indian ricegrass woodland occurs on just 613 acres in central Oregon, largely in the Lost Forest Research Natural Area of the federal Bureau of Land Management. The only known occurrence of the pitch pine/huckleberry shrubland is a single flat-topped summit in the Shawangunk Mountains of New York. Black greasewood/blue grama shrubland is limited to 1,000 acres in north-central New Mexico. And the Hempstead Plains grassland, which once covered 37,500 acres on Long Island, New York, is now represented only by 30 acres considered "severely degraded."

Not surprisingly, most of the plant communities that the Heritage\Conservancy identifies as imperiled fall into the major habitat categories that the NBS report identified as suffering the most severe losses in the United States — grasslands, savannas and barrens (Figure 2B). For example, many of the woodlands and sparse woodlands in Table 2, such as the "bur oak shale sparse woodland," would be labeled savannas or barrens in the NBS categorization[16].

Although many of the 130 rarest plant communities, such as eastern serpentine barrens, have been significantly reduced in area from their pre-European extent, others have not been so reduced. Although extremely rare, these latter have always been so, occupying very small areas because of quirks of biogeographic history or adaptation to unusual localized habitat conditions.

For example, the Heritage\Conservancy notes that the inland salt marsh (alkali bulrush-spearscale-spikerush) community is not noticeably rarer than it was 100 years ago. It is found on saturated saline mud flats associated with inland salt springs, a habitat not suitable for agriculture and not profitable at present to develop. Thus, rarity by itself is not adequate as an indicator of vulnerability or endangerment, at either the species level or the community-ecosystem level.

The Heritage\Conservancy system is useful for identifying extremely rare and special plant communities but is is not sufficient by itself for developing a national conservation strategy. A national strategy must recognize that rarity alone is not a sufficient measure of endangerment and should also include assessments of decline in area, imminence of threat, and other factors. Moreover, any strategy should consider not only plant communities but also special habitat types such as rivers, lakes and caves lacking from the Heritage\Conservancy report.

Attempts to compare states according to the number of Heritage\Conservancy rare plant communities are difficult at this stage because data quality varies so much from state to state. For example, plant ecologists in some states, such as Idaho and Oregon, have been more active than in others in identifying plant communities using the Heritage\Conservancy criteria. Thus, although Idaho has 26 identified critically imperiled plant communities under the TNC system — more than any other state — it is not clear to what degree this represents a real trend and to what degree it simply shows that Idaho has been very active in researching its biotic communities. The Heritage\Conservancy recognizes substantial information gaps for Alabama, Arizona, California, Florida, Georgia, Iowa, Maryland, Nevada, North Dakota, Rhode Island, South Dakota, Tennessee, Texas, Virginia, Utah and West Virginia. Either community classification systems in these states are lacking or are coarser than the present Heritage\Conservancy system or ranks have not yet been assigned to community types.

Which Ecosystems Have the Most Endangered Species?

Data on habitat associations of listed species are mostly anecdotal and few attempts have been made to tabulate all of the threatened and endangered species associated with a particular type of ecosystem. In part, this is because, until recently, the U.S. Fish and Wildlife Service has listed species under the Endangered Species Act one by one instead of together in a systematic fashion according to ecosystem. Similarly, single-species recovery planning has been more common than multi-species planning that focuses on ecosystems and habitat requirements shared by many species.

A recent U.S. Forest Service report, "Species Endangerment Patterns in the United States," listed general land-type associations of 667 federally listed threatened and endangered species (See Table 3, page 115)[17]. Forest habitats, especially evergreen forests, contain more threatened and endangered species than any other major habitat type. Wetlands contain a disproportionately large number of listed species for their limited area. Although wetlands comprise only about five percent of the land base in the conterminous United States, nearly 30 percent of listed animals and 15 percent of listed plants are associated with them. Considering only animals, more listed species are found in aquatic habitats, especially streams, than anywhere else. Rangelands (especially shrub-brush habitats) contain the most listed plants.

The Forest Service report also mapped the geographic distribution of federally listed species at the level of counties in the conterminous 48 states. Regionally, southern Appalachia, Florida, the arid Southwest and California stood out as hotbeds of endangerment. Listed animal species typically have larger ranges than plants, as most of the listed plants are narrow endemics* confined to small areas. For example, a great many listed plant species are restricted to the endangered sand-pine-scrub ecosystem on Lake Wales Ridge in south-central Florida[18]. These plants are thought to have evolved during interglacial periods with higher sea levels, when the patches of scrub along the ridge were islands surrounded by ocean.

* An endemic species is one found only in a limited area; thus, a species that is endemic to the San Francisco Bay area is found nowhere else in the world.

The NBS report, using data provided by the U.S. Fish and Wildlife Service and state agencies (especially the Natural Heritage Programs), provides detailed lists of threatened and endangered species associated with three major vegetation types — the longleaf pine and wiregrass ecosystem of the southeastern coastal plain, the coastal sage scrub of southern California and the old-growth forest of the Pacific Northwest. The longleaf pine and wiregrass ecosystem contains 27 federally listed species and 99 formally proposed or candidate species. Southern California coastal sage scrub contains 74 listed, proposed and candidate species, while the old-growth forests of western Washington, western Oregon and northwestern California support four listed species and 22 candidates.

Although these three NBS lists are useful, we urgently need lists of threatened and endangered species for all of the nation's major vegetation types, aquatic habitats and other ecosystems. Such lists would provide a strong foundation for ecosystem-based recovery planning for endangered and threatened species.

Which Ecosystems Face the Greatest Threats from Humans?

To assess the degree to which an ecosystem is endangered, we must analyze how greatly it is threatened by development or other harmful factors. An ecosystem may be highly endangered even if, like longleaf pine forest, it still covers hundreds of thousands of acres, so long as it is in an area undergoing rapid and uncontrolled development or resource exploitation. If a swamp ecosystem has declined by 90 percent since European settlement and a grassland by only 40 percent but the remaining swamp is now fully protected and the grassland is about to be plowed, conservation efforts probably should be directed first to the grassland.

Unfortunately, there has been no systematic attempt to determine which ecosystems or geographical areas nationwide are at greatest risk of being lost or seriously degraded. Reports are mostly anecdotal. However, data on human population and economic development trends are available at least on a state scale[19]. These trends correlate well with ecosystem destruction[20]. In general, the Southeast, Southwest, Pacific Northwest and Rocky Mountains are experiencing higher percentage population growth than the Northeast and Midwest. States adding the most people per square mile are Maryland, Florida, New Jersey, Delaware and California. States experiencing the greatest percentage population growth are Nevada, Arizona, Alaska, Florida, California and Washington (See Table 11, page 128). Areas near major population centers such as Los Angeles, San Diego, Seattle, Portland, Miami, Fort Myers and Orlando are especially at risk. (See Maps 4, 5 and 6, pages 21-22). Studies are urgently needed to determine the ecosystems unique to these areas that are at great risk of being lost. We know that some ecosystems, such as the pine rocklands of south Florida and the coastal sage scrub of southern California (See

DEFENDERS, Fall 1994) are in immediate danger of being destroyed by development.

The 21 Most-Endangered Ecosystems in the United States

Of the hundreds of imperiled ecosystems in the nation, we identified 21 ecosystems that are most endangered. We ranked them according to the four criteria discussed above: decline in original area since European settlement, present area (rarity), imminence of threat and number of federally listed threatened and endangered species.* Scores for the four criteria were developed on the basis of Reed Noss's expert knowledge and information from the NBS report (See Table 4, page 116).

The three highest-ranking ecosystems were the south Florida landscape, southern Appalachian spruce-fir forest and longleaf pine forest and savanna (See accompanying box). The south Florida landscape is defined geographically. It is a mixture of many different habitats and plant communities, such as the Everglades and the pine rocklands, which have the misfortune to occur in an area with burgeoning human population growth. The southern Appalachian spruce-fir forests, home to many rare and endemic species, are being attacked by a combination of acid fog[21] and, in the case of the Fraser Fir, by a deadly insect pest called the wooly adelgid[22]. The long-leaf pine forests and savannas, dominated by the fire-resistant longleaf pines, were once the primary vegetation type on uplands throughout the southeastern coastal plain of the United States. Today, in this area only two percent remains. Brief descriptions for all 21 ecosystems are present-

The 21 Most-Endangered Ecosystems of the United States

South Florida Landscape
Southern Appalachian Spruce-Fir Forest
Longleaf Pine Forest and Savanna
Eastern Grasslands, Savannas, and Barrens
Northwestern Grasslands and Savannas
California Native Grasslands
Coastal Communities in the Lower 48 States and Hawaii
Southwestern Riparian Forests
Southern California Coastal Sage Scrub
Hawaiian Dry Forest
Large Streams and Rivers in the Lower 48 States and Hawaii
Cave and Karst Systems
Tallgrass Prairie
California Riparian Forests and Wetlands
Florida Scrub
Ancient Eastern Deciduous Forest
Ancient Forest of Pacific Northwest
Ancient Red and White Pine Forest, Great Lakes States
Ancient Ponderosa Pine Forest
Midwestern Wetlands
Southern Forested Wetlands

* We recognize that our rankings do not translate directly into priorities for conservation action. Most conservation organizations or governmental agencies are likely to supplement risk with other criteria, including ecological value, scientific value and the economic and political feasibility of conservation. Therefore, although the ecosystems we have identified in Section 2 as being most endangered deserve very high conservation priority, we cannot say that any particular organization or agency should necessarily give them the highest conservation priority. Nonetheless, any scheme for setting conservation priorities should weigh risk heavily as a ranking criterion.

ed in Appendix B.

Each of the 21 ecosytem types is a wide category that groups a number of geographically smaller ecosystems, which are roughly on the geographic scale of the ecosystems listed in the NBS report or of the rare plant communities identified by the Heritage\Conservancy. For example, our ecosystem type called "eastern grassland, savanna and barrens" comprises many ecologically similar plant communities, including New Jersey pine barrens, Long Island pine barrens, New York serpentine barrens and New York maritime heathland. The majority of these plant-community ecosystems are rare or severely degraded. Examples include Hempstead Plains grassland of New York, of which less than a tenth of one percent remains, and bluegrass savanna-woodland in Kentucky, of which no intact example remains.

Most of our top 21 ecosystems have been seriously reduced in area, most have a substantial number of endangered species associated with them, and all are facing a high degree of human threat. For example, California native grasslands have greatly declined because of agriculture, grazing and invasion by exotic species and are increasingly threatened by development sprawl and other human activities. These grasslands are habitat for more than 25 threatened or endangered species (See California case study, pages 27-30).

SECTION TWO

Geographic Patterns of Risk to U.S. Ecosystems

Besides identifying which ecosystems are the most endangered, we also looked at which states are experiencing the greatest threats to their ecosystems and associated wildlife. Based on our Overall Risk Index (ORI), states had either extreme, high, or moderate risk of ecosystem loss. Because all states have substantial problems, there is no "low risk" category. States varied from Florida, which has the highest risk, to Alaska, Kansas, North Dakota and Wyoming, which tied for lowest risk.* Overall risk for all states is shown in Map 1 and Table 5 on pages 20 and 118. Summaries of risk statistics for all states can be found in Appendix D.

We could not directly measure how well or poorly all ecosystems in a state are faring because standardized information on ecosystem distribution and vulnerability is scarce. Therefore, we based the Overall Risk Index on a combination of factors that cause or indicate ecosystem loss. Specifically, we combined measurements of how much development is taking place, how many rare species there are, and how many of the 21 most-endangered ecosystems (identified in Section 1) occur in the state. Combined, these three factors give a good indication of the overall threat to a state's biological heritage — if uncontrolled urban sprawl is gobbling up the wild lands, then wildlife is diminishing along with the quality of human life. If a state has many endangered ecosystems, it means that many unique types of habitat are in danger of being lost forever. If a high percentage of the species occurring in a state is in danger of extinction, that state is clearly not doing an adequate job of protecting ecosystems, given that ecosystem loss and degradation are the primary causes of species

* The method by which we integrated information on endangered ecosystems, imperiled species and development to arrive at the overall risk to habitat and species is explained in Appendix C.

endangerment.

The Top 10 States: Extreme Risk

Ten states comprise the extreme risk group. In descending order of risk, they are Florida, California and Hawaii (tied), Georgia, North Carolina and Texas (tied), South Carolina and Virginia (tied), and Alabama and Tennessee (tied) (See Map 1). They are all coastal states and are either southern or western. Florida is at greatest risk by far, scoring 23 points on our Overall Risk Index, followed by California and Hawaii with 19 points apiece (See discussion of point system in Appendix C). The remaining extreme risk states scored between 15 and 17 points.

These states made the extreme risk group because in most cases they contain many endangered ecosystems and imperiled species and face high development pressure (See Table 6, page 119). Florida, for example, contains more of the 21 most-endangered ecosystems than any other state. Florida has all or part of nine of the nation's most-endangered ecosystems, including longleaf pine forest and savanna; beach and coastal strand; large streams and rivers; southern bottomland hardwood forests; eastern grasslands, savannas, and barrens; Florida scrub; ancient eastern deciduous forest; cave and karst systems; and the south Florida landscape as a whole.

Most of these states also have an extremely high percentage of imperiled species. For example, more than 13 percent of the vertebrates and plants in California and six percent of those in Florida are endangered. Between three and five percent of all the plants and vertebrates in Alabama, Georgia, North Carolina, Texas and Tennessee are in danger of extinction.* The Southeast has the highest known diversity of freshwater mussels in the world, yet the majority are endangered because of dams and secondarily, declining water quality. More than 25 percent of freshwater mussels in Alabama, Florida, Georgia, North Carolina, Tennessee, Texas and Virginia are imperiled.

Hawaii warrants special concern. Despite low development pressure compared to Florida and California, it has by far the largest number of endangered species of any state, including nearly a third of its native plants and vertebrates. The reasons include massive invasion by exotic species and conversion of most of its lowland communities to agriculture.

Many of the extreme-risk states are experiencing rapid population growth. In Florida and California, growth has been phenomenal, as described in the case studies. Between 1982 and 1992, population increased 29 percent in Florida and 25 percent in California. The result has been rapid destruction of native habitat. Between 1982 and 1992, more than three percent of the area of Florida was developed for housing and related uses — a

* "In danger of extinction" means "imperiled" or "highly imperiled" under The Nature Conservancy's ranking system for rare species. Data on at risk species was provided by The Nature Conservancy and the Network of Natural Heritage Programs and Conservation Data Centers.

34.6 percent increase in the amount of developed land. If this rate of increase were to continue indefinitely, all the potentially developable land in Florida would be covered with houses within 70 years. There are many practical reasons why complete development will not be reached, including Florida's aggressive land conservation program. Other states are booming as well: Georgia lost two percent and North Carolina lost three percent of its area to development during the same decade. If present development rates continue, North Carolina would be totally developed in 73 years and Georgia in 88 years*.

High-Risk States

Twenty-four high-risk states scored between 11 and 14 on our Overall Risk Index. High-risk eastern states are Connecticut, Delaware, Maryland, Massachusetts, New Jersey, New York, Pennsylvania and Rhode Island. Some of these eastern states, although not in the extreme-risk group, also are greatly threatened by development. In New Jersey, for example, the amount of developed land increased between 1982 and 1992 by 32 percent. If that trend were to continue, all unoccupied land in the state would be covered with buildings within 52 years. Other high-risk states are Arizona, Illinois, Indiana, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Nevada, New Mexico, Ohio, Oregon, Utah, Washington and Wisconsin.

State	Percent of state developed as of 1992	Percent increase in development 1982-1992	Years until entire state is developed
FL	12.4%	34.6%	70
GA	8.2%	32.8%	90
NC	10.5%	36.2%	80
NJ	31.9%	23.2%	60

For selected high-growth states, this box shows the projected length of time it would take to develop all undeveloped land in the state — including all agricultural and wild land — that was not already developed in 1992. See note below for assumptions and qualifications*.

Moderate-Risk States

Sixteen states scored between 10 and six. Plains states, including Colorado, Iowa, Kansas,

* In this projection we assumed that the rate of increase in developed land from 1982 to 1992 would continue into the future, compounding the amount of developed land every ten years. We expect compounding because as a region develops it attracts more people who in turn cause more development. We used a simple exponential growth formula where the finite rate of increase is the number of acres developed in 1992 divided by the number of acres developed in 1982. The amount of land developed at time t is $A_{1992}(\lambda)^{\tau}$, where A_{1992} is the developed area in 1992 and t is the number of 10-year intervals from 1992. In the case of Florida, the finite rate of increase is 4,645,000 acres divided by 3,452,000 acres = 1.35. The number of acres that would be developed in Florida in 70 years is 4,645,000 $(1.35)^7$ = 37,960,000, larger than the land area of Florida. We recognize that in reality land protection and other countervailing forces will slow development before all presently undeveloped land is developed. Nonetheless, our estimate of time until complete development gives a good indication of the extent of development threat in a state and shows that present development rates are unsustainable over the long term. Data is from *U.S. Bureau of the Census*.

Montana, Nebraska, North Dakota, Oklahoma, South Dakota and Wyoming, are heavily represented. Vermont and Maine scored seven, reflecting their low population densities and relatively small agricultural areas. Other moderate-risk states are Alaska, Arkansas, Idaho, Kansas and West Virginia.

Although states at the top of the list clearly face major challenges, lower-ranking states should not be complacent. For example, Iowa has a low overall risk score of eight, in large part because it has low rates of population growth and development and relatively few large urban centers. Nonetheless, Iowa has lost much of its native biodiversity and has many state-listed endangered and threatened species (See case study, pages 35-37). The primary cause is extensive agricultural development — 93 percent of Iowa is agricultural land — which has destroyed tallgrass prairie, wetlands and other ecosystems.

Alaska, although one of the lowest-ranking states, has significant problems. Its large land area relative to the number of people suggests that human impacts would be negligible, but this masks the fact that heavy timber cutting is concentrated in the relatively small portion of the state with quality old-growth forest, particularly in the Tongass National Forest and nearby areas. This old-growth forest is optimal or required habitat for a number of potentially threatened or endangered species, including the Queen Charlotte goshawk, Alexander Archipelago wolf and marbled murrelet. So little biological information exists on some southeast Alaska species that they have not even been formally described.

Other Indicators of Risk

As described in Appendix B, the overall risk to a state's habitats and wildlife was calculated using measures of endangered ecosystems, imperiled species and development. Maps 2 through 6 show relative rankings of the states according to these criteria. Here we describe the three indicators and associated state rankings:

• **Indicator 1: Endangered Ecosystems.** Our Ecosystem Risk Index is a measure of how many of the 21 "most-endangered" ecosystems are found in a state (See Section 1, page 10; Appendix B, page 54). Map 2 color-codes the states according to how many endangered ecosystems they contain. The substantiating data are presented in Table 9. The majority of states with many of these highly endangered ecosystems are either in the South or Midwest, areas where conversion of native habitats to agriculture has been extensive. Florida has the most endangered ecosystems, followed by Alabama, California, Michigan, Minnesota, North Carolina, Ohio, Texas and Wisconsin (all eight are tied for second place)

• **Indicator 2: Imperiled Species.** The Species Risk Index is a scaled score combining percentages of each state's native plants, vertebrates and aquatic invertebrates that are imperiled or highly imperiled. Map 3 color-codes the states according to Species Risk Index score. According to this index, the top states in rank order are:

(1) Hawaii

(2) California and Florida (tied)
(3) Alabama, Georgia, Nevada, Tennessee, Texas and Utah (tied)

States with a high percentage of imperiled species are primarily found in the South and West. States in the East and Midwest and on the Great Plains have relatively low proportions of high-risk species. Raw data on the number of endangered plants, vertebrates and freshwater mussels and crayfish in each state can be found in Table 8 (page 123). Crayfish and mussels were used as components of the Species Risk Index because they are among the few invertebrate aquatic groups for which there are reasonably good data on conservation status.

- **Indicator 3: Development Threat**. The third index used to calculate overall risk to habitats and species is the Development Risk Index (See Map 4, page 21), which combines measures for population density, percentage of agricultural land, percentage developed land and rural road density. The states with the 13 highest development threat scores are:

(1) Florida and New Jersey (tied)
(2) Delaware and Maryland (tied)
(3) Massachusetts and Rhode Island (tied)
(4) California, Connecticut, Georgia, North Carolina, New Hampshire, South Carolina and Virginia (all eight are tied)

In addition, we divided the Development Risk Index into two subindices. One, the Development Status Subindex, shown in Map 5, is based on percentage of developed land and other measures that show the degree to which a state has already been developed. The second, shown in Map 6, is the Development Trend Subindex, which is based on the percentage change in developed land and other measures that show how rapidly development is occurring now.

By reviewing the supporting data for these development maps (See Tables 10 and 11, pages 126 and 128), one can understand the development pressures facing each state. Midwestern states typically scored high on the Development Status Index because so much land has already been converted to agriculture and extensive networks of rural roads. Eastern states also scored high, but for different reasons — while they have relatively little farm land and few rural roads, they have much developed land and very high population densities. States that scored high on our Development Trend Index, indicating rapid increases in development and population during the past decade, are primarily coastal (See Map 6, page 22). This distribution pattern looks very similar to the pattern of the Species Risk Index in Map 2, showing a coincidence between the regions where there is a high rate of development and a high proportion of at-risk species. One interesting result is that Maryland and New Jersey, which already have extremely high densities of over 470 people per square mile, are still growing — adding more than 50 people per square mile between 1982 and 1992 — and growing faster than any other state except Florida.

Geographic Patterns of Overall Risk

Because neighboring states often have generally similar topography, climates, plant and animal life and histories of human use, they also have generally similar levels of overall risk. For example, southern states typically have extreme levels of overall risk, while plains states have moderate risk. The maps do not show a high correlation between the distribution of states with high percentages of imperiled species and states with high numbers of endangered ecosystems.* For example, although midwestern states have relatively few imperiled species, they score as moderate to high in number of endangered ecosystems. This midwestern pattern is partly traceable to extensive conversion of natural ecosystems to agriculture. On the other hand, many of the most highly endangered ecosystems — south Florida landscape, longleaf pine, eastern savanna and barrens, and California coastal sage scrub — have numerous imperiled species associated with them.

In the following discussion, the numbers in parentheses are the scores the states in a region received on our indices for imperiled species, ecosystems and development. See Table 7 for regional summaries of risk scores.

Eastern States

Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and West Virginia.

Overall risk: *moderate to high*
Imperiled species: *moderate*
Endangered ecosystems: *high*
Development: *high to extreme*

Eastern states, except for Maine, Vermont And West Virginia, have high levels of overall risk, with most scores on the Overall Risk Index ranging from 11 to 15. They have relatively few imperiled species (scores of 2 or 3), high numbers of endangered ecosystems (typically scores of 4 to 5) and mixed levels of development (scores of 1 to 8). See the New York case study (page 32) for a description of development activities and resulting biodiversity loss in the southern part of the state, particularly on Long Island. Maine, Vermont and West Virginia are exceptions in that they have relatively low development risk (scores of 1 to 3), giving them overall risk scores of 7 and 8.

Plains States

Iowa, Kansas, Montana, North Dakota, Nebraska, Oklahoma, South Dakota, Wyoming and Colorado.

Overall risk: *moderate*

* When describing a state's status with respect to imperiled species, endangered ecosystems or development risk, we use the terms "extreme," "high" and "moderate." In each case, these terms indicate how the state scored on either the Species Risk Index, Ecosystem Risk Index or Development Risk Index. We use the term "extreme" to denote a score of 6 to 8, "high" to denote a score of 4 to 5, and "moderate" to indicate 1 to 3. We purposely did not have a "low" category because there are no states without substantial problems. A moderate score for a particular state indicates not lack of a problem, but that the state is in somewhat better shape than some other states according to the criterion in question. For example, Ohio could rate "moderate" on the Species Risk Index while nonetheless having 24 percent of its mussel species imperiled, an unacceptable situation. The percentage of imperiled species and endangered ecosystems for each state is shown in Table 8 (page 123).

Imperiled species: *moderate*
Endangered ecosystems: *moderate to high*
Development: *moderate*

The plains states generally have moderate levels of overall risk. All have relatively low levels of development risk, scoring 1 or 2 on our Development Risk Index. They have moderate percentages of imperiled species. Oklahoma's score of 4 on the Species Risk Index was the highest. Scores on the Ecosystem Risk Index are predominantly moderate.

Midwestern States

Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio and Wisconsin.
Overall risk: *high*
Imperiled species: *low to moderate*
Endangered ecosystems: *extreme*
Development: *low to moderate*

Most midwestern states have high overall risk. All have relatively moderate percentages of imperiled species (scores of 2 to 4), high to extreme numbers of endangered ecosystems (scores of 5 to 7), and relatively low development (scores of 2 to 4). Although population growth and development are currently low for these states, giving rise to the moderate development scores, past human impacts have been heavy, as shown by the data presented in Table 10. The percentage of agricultural land is high for all these states, ranging from 48 to 78, reflecting the extensive clearing that has reduced tallgrass prairie by 99 percent and has led to comparable losses of the presettlement forest.

Southern States

Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia.
Overall risk: *high to extreme*
Imperiled species: *high to extreme*
Endangered ecosystems: *mixed, predominantly extreme*
Development: *moderate to extreme*

These have high to extreme percentages of imperiled species (scores of 4 to 7), predominantly extreme numbers of endangered ecosystems (scores of 4 to 7), and mixed levels of development from very low to extreme (scores of 1 to 8). The high scores on the Species Risk Index reflect very large numbers of imperiled plants and vertebrates in some states, such as Tennessee (6 percent of vertebrates imperiled), and extraordinarily high percentages of imperiled freshwater invertebrates (39 percent of mussels imperiled in Alabama).

Southwestern States

Arizona, California, New Mexico, Nevada, Texas and Utah.
Overall risk: *high to extreme*
Imperiled species: *high to extreme*
Endangered ecosystems: *mixed, moderate to extreme*
Development: *moderate to high*

California and Texas have extreme numbers of endangered ecosystems (scores of 7), while the other states in this group have moderate scores (all 3). The development threat is moderate to high, and percentages of at-risk species are high to extreme (scores of 5 to 7). One cause of this pattern of very high species risk but relatively low numbers of endangered ecosystems is concentration of human settlement and resource use in southwestern riparian zones. Although many western ecosystems are relatively undisturbed, scarce aquatic habitats in desert environments have been heavily damaged, with a resulting threat to many species.

Northwestern States

Idaho, Oregon and Washington.

Overall risk: *moderate to high*

Imperiled species: *moderate to high*

Endangered ecosystems: *moderate to high*

Development: *moderate to high*

These states have lower overall risk than most of the southwestern states. This is partly a function of relative development impact. The Development Risk Index is lower than for the southwestern states, California, Texas, Nevada and Arizona. In addition, what development occurs is not as restricted to riparian areas. The result is that a smaller percentage of species are endangered than in most of the southwestern states. Scores on the Ecosystem Risk Index are high (scores of 5) for Oregon and Washington, reflecting in part extensive clearing of old-growth forest.

Hawaii

Overall risk: *extreme*

Imperiled species: *extreme*

Endangered ecosystems: *moderate*

Development: *high*

Hawaii has exeptionally high numbers of endangered endemic species due to a combination of habitat destruction and exotic invaders (See Hawaii case study, pages 30-32).

Alaska

Overall risk: *moderate*

Imperiled species: *moderate*

Endangered ecosystems: *moderate*

Development: *moderate*

In spite of relatively low scores, Alaska has significant threats to some ecosystems (page xiii).

Color Maps

Color Maps

Color Maps

SECTION THREE

State Case Studies

The analysis in the preceding section tells us where the problem is worst: the state with the most endangered ecosystems and the greatest overall risk is Florida. The coastal states, where most people live, face a tremendous challenge. Southern states are generally more at risk than northern ones. Capsule summaries of risk statistics for all states can be found in Appendix D.

Causes of risk, which include habitat loss, introduced species, fire suppression and global warming, are discussed in detail in Appendix A. Development is behind much of the problem. We have identified states such as Florida, North Carolina and Georgia that are growing so fast in human population and development they theoretically could be mostly concrete and lawns within 80 years. But how exactly does this development affect ecosystems? What threats do human activities pose? To which ecosystems?

One way to get answers to these questions is to look more closely at specific states and specific ecosystems. In this section we present five state case studies in order to illustrate how economic development and associated human activities have changed the natural environment. These states are Florida, California, Hawaii, New York and Iowa.

Although each of our case studies represents a different region of the country and therefore has distinct topography, climate, ecosystems, wildlife and human history, the overall effect in each case has been much the same — dramatic reduction in natural environments and associated wildlife. Three of our states, Florida, California and Hawaii, are identified as having the highest overall risk to ecosystems of any in our analysis (Section 2). The other two, New York and Iowa, scored relatively low on our risk analysis. Nonetheless, New York and Iowa have substantial problems, and their case studies show that even "moderate risk" states have had substantial losses of natural ecosystems and the native species that depend on them.

In presenting the case studies,

we took a historical approach to illustrate how past land-use patterns have affected composition and distribution of ecosystems. Iowa, for example, reflects a worst-case scenario in which virtually no refuge land was set aside and most natural ecosystems were converted to farms during the 19th and early 20th centuries prior to the evolution of a conservation ethic. Florida, on the other hand, although facing an extraordinary development threat, is pursuing an aggressive strategy of land conservation, in part because recreational use of natural resources is a major source of income for the state.

Florida

Florida ranks fourth in the contiguous United States in terms of overall species richness and has more species than any other state east of the Mississippi River[23]. More than 3,500 vascular plants and 425 bird species are found in Florida, along with 184 species of amphibians and reptiles, 126 fishes and 75 mammals[24]. Florida's near-tropical location, high humidity and wide range of soils (from an ancient 25 million years old to a mere 2,000 to 3,000 years)[25] have produced a biota distinct from those elsewhere in the United States. Many species, including almost 8 percent of vascular plants and a large but unknown number of insects, are endemic[26]. Others, including ironwood, white stopper and gumbo limbo, while not endemic, are representatives of tropical biota not found in other areas of the nation[27].

Unfortunately, much of the state's diversity may disappear in coming decades because of a steady increase in residential and agricultural development. The pine rocklands of south Florida are one of the most endangered natural communities in the United States[28]. Restricted to thin, well-drained soils located above outcroppings of Miami limestone, the pine rocklands ecosystem once covered 382,000 acres of the southern tip of the peninsula and along the lower Florida Keys[29]. These fire-dependent forests provide habitat for a variety of plants and animals, including the federally endangered Key deer and Lower Key marsh rabbit and many rare and endemic plants[30]. In the last few decades, rapid development in southern Florida has reduced the pine rocklands to only two percent of their original extent[31]. The remaining fragments are generally in poor condition because of fire suppression, invasion by exotic species such as the Brazilian pepper and the continuing intrusion of roads and development[32].

Also endangered are the long-

FLORIDA

LOSSES

- Pine rocklands reduced 98 percent
- Longleaf pine forest reduced 88 percent since 1936; quality stands of longleaf pine reduced by approximately 98 percent
- Tropical hardwood hammocks in the Keys reduced 60 to 80 percent
- Florida dry prairies are virtually all converted to cattle pasture and agriculture
- Florida scrub reduced 65 to 75 percent

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leaf pine forests of the coastal plain, once Florida's dominant forest type. Also known as sandhill and flatwoods communities, these systems of longleaf pine, native grasses and forbs (with turkey oak a major subcanopy tree on sandhill sites) originally stretched from Virginia to eastern Texas, covering approximately 6.9 million acres in Florida's upper peninsula and panhandle regions[33]. Subject to low-intensity ground fires every few years, these forests are home to hundreds of species, including the federally endangered red-cockaded woodpecker and the declining gopher tortoise[34]. Biologists estimate that nearly 400 species of animals, including the threatened indigo snake and Florida mouse, use the burrows of the gopher tortoise during some part of their life cycles[35]. Several species of insects are found only in gopher tortoise burrows[36].

Destruction of longleaf pine forests began in earnest after the Civil War and has accelerated in the last 50 years[37]. Since World War II, Florida's longleaf pine forests have been cut at an annual rate of 130,000 acres[38] and largely replaced by single-species plantations of slash pine[39]. Unfortunately, these plantations do not support nearly the diversity of the original sandhill and flatwoods communities[40]. As with the pine rocklands, habitat fragmentation and alteration of the natural fire regime have left the remaining longleaf pine forests in poor condition[41].

Some of the rarest, most distinctive animals and plants in Florida can be found in the dry scrub communities that are nearly unique to the state[42]. Originally ecological islands within a matrix of longleaf and south Florida slash pine forests, scrub once extended across a million acres. Now less than half remains[43]. In Florida's rapidly developing Central Ridge region, over 80 percent of the scrub has been converted to urban or agricultural use[44]. Of the estimated two dozen plant species endemic to Florida scrub, 13 are federally listed as threatened or endangered, along with the scrub jay and two lizards, the sand skink and mole skink[45]. In addition, virtually all of the state's dry prairie has been lost to agriculture or used for livestock grazing[46], and between 60 and 80 percent of the tropical hardwood hammocks once found in the Keys have been destroyed[47] (See front cover for a photograph of a tropical hardwood hammock).

More than half of Florida's wetlands have been drained or developed[48]. Everglades National Park was one of the first national parks established to protect functional ecosystems rather than just scenery, yet American Rivers recently listed the Everglades as one of the top five most threatened eastern river systems in the United States[49]. Agriculture and development have interrupted the vital water flow across the Everglades and polluted it with pesticides and mercury[50]. Over 65 percent of the 3,900-square-mile Kissimmee-Okeechobee-Everglades system has been drained and converted to a managed water-control system[51]; the region's wading bird flocks, estimated to have once numbered more than 2.5 million birds[52], have declined by 90 percent[53].

Along the coast, Florida's salt marshes have been degraded by development and impoundment for mosquito control, especially near Tampa Bay and along the Indian River[54]. Florida Bay is becoming severely degraded as a result of alteration of freshwater inflows from the Everglades[55]. Coastal development also has reduced the delicate strand communities along the sand dunes by more than half[56]. These are probably the most rapidly disappearing biological communities in the state, according to the Florida Natural Areas Inventory[57].

Exotic plant species pose severe problems for Florida's native species and ecosystems, particularly in the southern part of the state. Three species stand out as especially problematic in terrestrial systems. Brazilian pepper, whose bright red berries are spread by birds, has invaded much of south Florida after being planted as an ornamental[58]. Australian pine, planted as a windbreak and to stabilize beaches, has become so dense on many beaches that virtually nothing else grows in what once were diverse coastal strand and dune communities[59]. Melaleuca, originally from Australia, has taken over many wetlands, primarily in the Everglades region, and is proving extremely difficult to control[60]. Aquatic systems in Florida are often choked with exotic plants. Hydrilla, introduced by the aquarium trade in the early 1960s, outcompetes many native species on the water surface and shades other plant species growing below. Water hyacinth was introduced from South America in the late 19th century and now clogs many waterways, crowding out native plants and changing water chemistry[61].

In the last 150 years Florida has lost at least 34 species or subspecies of native plants and animals[62]. Some, such as the red wolf, are being reintroduced elsewhere in the Southeast, but others such as the dusky seaside sparrow and Carolina parakeet have vanished forever[63]. According to the Florida Biodiversity Task Force, 44 percent of the state's non-marine vertebrates are declining[64]. The Florida panther, Key deer, American crocodile, and Florida black bear and 113 other animal species are listed by the state as endangered, threatened or of special concern[65], and more than 200 species of plants are listed or candidates for listing under the federal Endangered Species Act[66]. Florida has more federally listed species than any other state except Hawaii and California.

Most of Florida's explosive growth and ecological destruction has occurred in the last century. Since 1936 Florida's population has grown from 1.7 million to almost 14 million[67]. It is estimated to have increased more than 28 percent between 1980 and 1990[68] and is projected to reach 16 million permanent residents by the year 2000, a net increase of 1,000 people a day during the 1990s[69]. In addition, an estimated 39 million tourists visit the state each year[70]. Urban and agricultural development also have accelerated over the last 50 years. Every year, croplands and rangelands have expanded an average of 83,000 acres, while urban areas have expanded an average of 77,100 acres[71]. Few old agricultural lands have been restored to their original native condition. Many have been converted to suburbs. The rest have generally not recovered fully and remain marginal or poor wildlife habitat[72].

Most Florida residents and visitors are aware that the state is the home of spectacular wildlife. According to the Florida Game and Fresh Water Fish Commission, nature enthusiasts pumped $1.3 billion into the state's economy in 1985 alone[73]. Consumptive uses of wildlife (such as hunting and fishing) produced $3.8 billion. Natural area recreation qualified as the second-largest "industry" in the state in 1985[74] and has probably increased since then. Because many Floridans support wildlife conservation, more money has gone into acquiring land for conservation in Florida than in any other state[75]. Collectively, state and county agencies spent over $300 million each year for the last several years buying natural habitat[76]. Yet even this spectacular financial commitment has not been enough to offset the ecological destruction fueled by human population growth. In 1994, a Florida Game and Fresh Water Fish Commission report on the gaps in Florida's nature conservation strategy[77], recommended adding 4.8 million acres to the 6.9 million already under some form of protection. At an estimated average purchase price of over $1,100 per acre, this would cost more than $5.7 billion[78]. Accomplishment of this objective appears unlikely, but unless significant measures are taken soon to curb the state's runaway growth, many of Florida's unique biological treasures may be lost.

CALIFORNIA

LOSSES

- Native grasslands reduced 99 percent
- Needlegrass steppe reduced 99.9 percent
- Southern San Joaquin Valley alkali sink scrub reduced 99 percent
- Southern California coastal sage scrub reduced 70 to 90 percent
- Vernal pools reduced 99 percent
- Wetlands, all types, reduced 91 percent
- Riparian woodlands reduced 89 percent
- Coastal redwood forests reduced 85 percent

California

California's varied topography and 20 regional climate zones[79] make it rich in biodiversity. An estimated 380 distinct natural communities provide habitat for more than 4,400 species of vascular plants[80] — more species than the central and northeastern United States and Canada combined[81]. Many of California's 40,000 species of animals and plants[82] can be found nowhere else: 38 percent of the state's native freshwater fish species, 31 percent of its vascular plants, 29 percent of its amphibians and almost 10 percent of its mammals are endemic to the state[83]. Its Mediterranean climate, characterized by hot, dry summers and cool, wet winters, is unique in the United States except for a small area of Oregon and occurs in only a handful of regions throughout the world[84].

California is also one of our most ecologically degraded states. The Nature Conservancy considers nearly half of California's natural communities rare or threatened[85]. Some, such as the pebble plains in the San Bernadino Mountains and the forests of Torrey pine in San Diego County, are naturally rare because they have long been restricted to special sites. But other ecosystems such as California's native grasslands and riparian cottonwood forests were widespread before humans reduced them.

All or part of eight of the nation's most-endangered ecosystems are in California, including beach and coastal strand, southern California coastal sage scrub, large streams and rivers, California riparian forests and wetlands, California native grasslands, old-growth ponderosa pine forests, cave and karst systems and the ancient forests of the Pacific Northwest, including the coastal redwoods. Native grasslands originally covered almost a quarter of the state, primarily in the Sacramento and San Joaquin valleys[86]. Of the original 22 million grassland acres, fewer than 220,000 or less than 1 percent, remains[87]. The other 99 percent has been plowed under for crops, grazed away by livestock, invaded by introduced plant species or covered by expanding urban development[88]. Also gone are 99.9 percent of the needlegrass steppe[89], 90 percent of the north coastal bunchgrass[90] and 68 percent of the alpine meadows[91]. With the valley grasslands have disappeared most of the once-common vernal pools, small seasonally damp depressions in the meadows that were habitat for more than 100 distinct species[92]. Today less than one percent remains[93].

California's wetland and riparian communities have fared no better than its grasslands. Ninety-one percent of California's original 5 million acres of wetlands has been drained or filled[94], and wetlands continue to be lost at a rate of almost 5,000 acres per year[95]. The remaining fragments are essential to the millions of snow geese, whistling swans and other water birds that migrate annually along the Pacific Flyway[96]. Coastal salt marshes have been reduced by 62 percent[97], while 80 percent of the coastal wetlands have been converted to urban or agricultural uses[98]. Ninety percent of the thousands of acres of riparian forest that once bordered California's rivers and streams has been cut for timber or cleared for grazing and industrial development[99].

In the northwestern part of the state, 85 percent of the coastal redwood forests, home to the world's tallest trees, has been lost[100]. Between 70 and 90 percent of the original presettlement coastal sage scrub also has been destroyed[101]. Off-road vehicles and invading grasses have degraded 99 percent of the delicate strand communities that once covered the shifting dunes of the sandy southern coast[102]. Fire suppression and development have altered the dry, scrubby chaparral communities, leaving them unable to support many fire-dependent species and, ironically, increasingly prone to catastrophic fires because of the accumulation of dead fuel wood[103]. And in the fragile southern desert, where the tracks of Patton's tanks are still clearly visible after 50 years[104], 99 percent of the alkali sink scrub, a community specially adapted to the dry, salty soils of the southern San Joaquin Valley, has been lost[105].

As ecosystems become endangered, so do the species that inhabit them. For example, 94 plant and animal species are dependent on the rapidly disappearing coastal sage scrub of southern California[106]. Seventy-four of these species are federally listed, proposed for listing, or candidates for listing under the Endangered Species Act, including the endangered Palos Verdes blue butterfly and the threatened coastal California gnatcatcher[107]. California has more federally listed threatened and endangered species than any other state[108]. Statewide, biologists estimate that a quarter of the state's plant and freshwater fish species are currently threatened with extinction, along with 10 percent of the state's mammals and 6 percent of its birds[109]. At least 70 species of plants and animals have already gone extinct in California as a direct result of hunting or habitat degradation, including the state symbol, the California grizzly bear[110]. The bear was once the largest predator in the contiguous United States but could not withstand an extermination campaign waged by ranchers and other economic interests. The last California grizzly was probably killed in 1922[111]. The estimates of extinct species are almost certainly an understatement, since the extinction of some species — particularly invertebrates — has undoubtedly gone unnoticed.

Almost 45 percent of California is public land owned by the federal, state or local governments[112]. Yet very few of these areas have been managed for the protection of biodiversity. As with many other states, the largest protected areas are those unsuitable for agriculture or grazing, such as the rugged slopes of the Sierra Nevada[113]. To its credit, California has tried to shape its own future. In 1970, the legislature enacted both the California Environmental Quality Act and the California Endangered Species Act, indicating a new commitment to preserving the state's biological heritage. Help from the federal government came in 1994 with congressional passage of the California Desert Protection Act, to protect over 7 million acres of rare and fragile desert ecosystems[114]. A number of aggressive restoration programs are trying to reverse some of the damage, returning old farms to wetlands, planting new valley oaks and creating new perennial native grasslands[115]. It remains to be seen whether these and other conservation strategies across the state will succeed in saving and restoring California's endangered ecosystems.

The challenge of reversing ecosystem decline is substantial because of the state's burgeoning population. Between 1982 and 1992, California's population increased from 20 million to 30 million — 100 new residents every hour — and it is projected to double to 60 million within the next 50 years[116]. As the cities expand, their suburbs swallow up 45,000 acres of habitat annually[117]. In a state where one out of every three acres is already farmed or grazed[118], there may soon be little room left for California's remarkable biological diversity.

Hawaii

The Hawaiian Islands, once a tropical paradise, are now an ecological disaster. According to Hawaii's Department of Land and Natural Resources, 85 of Hawaii's 150 natural biotic communities are currently endangered[119] and, with the exception of a few high-altitude mountain communities, all of its natural ecosystems are degraded to some extent[120]. So many extinctions have occurred that key ecological components are missing from many ecosystems. For example, the only known pollinator for Kauai's Brighamia, an endemic lobelia, has been lost, so that biologists must pollinate the few remaining plants by hand[121].

Hawaii is biologically unique. Because the islands are separated from their nearest neighbor by more than 435 miles of ocean, they developed over millions of years a biota rich in species found nowhere else[122]. Almost all of Hawaii's native insects, 98 percent of its birds, 93 percent of its flowering plants, and 65 percent of its ferns are endemic to Hawaii[123]. Imperiled native plants include the Haleakala silversword (a six-foot-tall relative of the common daisy) and the koa and mapane trees[124]. Endangered endemic birds include the nene (a goose that is the state bird), the Hawaiian crow and many songbirds such as the Kauai thrush and the Oahu creeper[125]. Hawaii has only one native land mammal, the hoary bat, and no reptiles or amphibians.

The first people to change the native ecosystems were the Polynesians, who arrived approximately 2,000 years ago. They cleared the lowland forests for agriculture, converted the coastal wetlands to fishponds and irrigated fields and introduced rats, dogs, pigs and jungle fowl[126]. These changes ultimately brought about the extinction of 53 percent of Hawaii's original 82 bird species[127]. One species each of sea eagle, hawk, honey eater and ibis were lost as were at least six species of goose, six species of owl and 15 species of Hawaiian finch[128].

A second period of ecological devastation began with the arrival of Captain Cook in 1778[129]. By the middle of the 19th century, extensive tracts of lowland forest had been cut for firewood and the sandlewood trade or cleared for commercial agriculture, particularly sugar cane[130]. By the late 19th and early 20th century, settlers moved to the upland forests, rapidly converting them to cattle pastures[131]. Two thirds of the original forest cover is now gone, including 50 percent of the only tropical rainforests in the United States[132].

HAWAII

LOSSES

- Dry forests reduced 90 percent
- Original forest, all types combined, reduced 67 percent
- Mesic forest and mesic shrubland on main islands reduced 61percent
- Has 25 percent of the nation's federally listed endangered species and 72 percent of the nation's recorded extinctions

Today, more than a million residents and 6 million tourists a year occupy the lowlands, greatly disturbing the natural ecosystems[133]. The coastal zone has been particularly hard hit by development, and one major ecosystem type, coastal wet forest, is extinct[134]. Also much reduced are a variety of dry and mesic forests and shrublands that originally covered the dry leeward slopes in the rainshadow of the mountains[135]. Dry forests, reduced 90 percent[136], contain many rare forest trees, including the native hibiscus *Kokia*, which is nearly extinct in the wild[137]. In the upland woodlands, regeneration of many native, dominant tree species rarely occurs because of excessive grazing by cattle and sheep[138].

Exotic species are another tremendous problem in Hawaii. Because Hawaiian species and ecosystems evolved in relative isolation, they are much more vulnerable to exotics than those of the mainland. For example, because no large grazing animals evolved in Hawaii, many of the native plants lack protective thorns and unpalatable chemicals, and do not regenerate well after being browsed or grazed[139]. The introduction of domestic grazing animals such as cattle and pigs has favored the spread of introduced plants adapted to grazing and other types of disturbance[140]. Approximately 5,000 species of seed plants have been introduced in Hawaii, which has only about 3,000 native species[141]. In many areas, particularly the lowlands, the vegetation is now composed almost entirely of exotic species[142]. Common dominant exotics include the American mangrove, strawberry guava, fountain grass, silk oak and banana poka, a passion flower vine that has already smothered more than 70,000 acres of forest[143].

Associated with habitat destruction and invasion by exotics has been an unprecedented loss of species. Since Captain Cook's arrival, at least 23 native bird species and 177 species of native plants have become extinct in addition to those previously eliminated by the Polynesians[144]. An additional 30 bird and other animal species and 185 plant species are currently listed under the Endangered Species Act[145]. Today, although the state comprises less than two tenths of one percent of the nation's total land area, Hawaii contains more than 25 percent of the federally listed endangered species and has suffered 72 percent of the nation's recorded extinctions[146]. Despite conservation efforts seven species of native birds are thought to have become extinct since 1963, five of them during the 1980s, including the Oahu creeper, last seen in 1985[147].

Efforts to save Hawaii's native ecosystems include protection of more than a million acres of natural areas in a network of state, federal and private preserves[148]. Captive-breeding programs are under way for the nene, Hawaiian duck, Hawaiian crow and more than 100 species of native plants, with the goal of eventual reintroduction in the wild[149]. Nonetheless, the overall prognosis for Hawaiian ecosystems is poor. Thirty of the state's 95 coastal and lowland plant communities are not represented in the designated protection areas[150]. Most native species are not amenable to captive propagation, and even when propagation succeeds, reintroduction is likely to fail if the original causes of mortality remain. Exotic species continue to expand their ranges, and new ones will slip into the country even though Hawaii has the most stringent regulations of any state against importation. As clearing of the forests and development of private land escalates, so will the number of ecosystems and species lost.

New York

At the time of European settlement, most of New York was covered with hardwood forests of beech, maple and basswood[151]. These forests were cleared rapidly for agriculture, settlements and firewood (a typical 18th century household burned an acre of wood per year[152]). After a century of extensive clearing, New York's forests were reduced to a fraction of their former extent. For example, forest cover in Thompkins County in central New York went from 100 percent in 1790 to less than 20 percent in 1900[153].

The coastal and southern portions of the state were blessed with easy access to trade and rich, level soils for farming. These regions were heavily settled, producing today's string of large cities, such as Albany, Syracuse, Rochester and Buffalo, that stretch in an east-west band through the center of the state. A growing metropolitan area surrounds each of these cities as well as the largest city in the region, New York City. Not surprisingly, the natural ecosystems in these heavily developed regions have fared poorly.

In the northern part of the state poor soils discouraged agriculture, so many of the natural ecosystems remained relatively intact[154]. In these areas, logging has been the major source of change, and most of the northern forests, including millions of acres in the Adirondack Mountains, have been cut or burned at least once[155].

After 1900, forest cover began to return as areas once cleared for agriculture or cut for timber were abandoned[156]. Today, Thompkins County is 50 percent forest[157], and there are now 6 million acres of forest in the Adirondacks[158].

NEW YORK

LOSSES

- Long Island Hempstead Plains grassland reduced 99.9 percent
- Many coastal ecosystems reduced more than 90 percent (e.g. maritime oak holly forest)
- Many wetland ecosystems reduced 70 to 90 percent (e.g. freshwater tidal swamp)
- Long Island Pine Barrens reduced 60 percent
- Many poor-soil communities reduced 70 to 98 percent (e.g. serpentine barrens reduced 98 percent)
- Has 88 endangered, threatened or special concern* species

Although there is a great deal of second-growth forest, relatively little old growth remains[159]. Nonetheless, the Adirondacks

* Special concern species have not yet been listed as endangered or threatened but have been identified by the state as vulnerable to extinction because of declining population size, rarity or some other factor.

contain the largest blocks of old-growth forest in the eastern United States, totaling between 60,000 and 200,000 acres[160].

Despite forest regrowth, New York contains some of the most seriously depleted ecosystems in the country. These include some rare forest ecosystems, such as Allegheny oak forest, which has been reduced to less than 5,000 acres[161] and continues to be threatened by logging and development. A study by the New York Department of Environmental Conservation showed that development is the primary threat to most of New York's native ecosystems, followed by damage from off-road vehicles, hikers or cattle, hydrologic changes, grazing, lumbering and pollution[162]. A recent study on Staten Island illustrated how harmful development can be. Despite the fact that ten percent of the island is protected, 443 plant species (40.9 percent of the total)[163] became extinct on the island between 1879 and 1981, and the researchers predict that more will be lost as the conversion of fields and forests to housing continues.

One ecosystem endangered throughout the eastern United States is old-growth deciduous forest[164]. Old growth of even the most common deciduous types, such as northern hardwoods, is now reduced within New York to a few remnants, primarily within Adirondack Park and to a lesser extent Catskill Park[165] and other scattered mountain sites. The secondary forests cropping up on abandoned agricultural land and timber harvest sites are different from old growth; not only do they lack such structural elements as large old trees, but they also typically have a different plant species composition from the original forests[166]. Many deep forest herbs and wildflowers may be rare or missing from secondary forests because they did not survive the period when the land was used for agriculture[167]. Heavy logging may also have removed certain species such as eastern hemlocks, 20 million of which were cut during the 19th century for making tannin[168]. Logging of all types of softwoods, including white pine, has changed much of the Adirondack forest from a mixture of hardwoods and softwoods to almost pure hardwood stands[169].

Other ecosystems have fared worse than forests. Since the colonial period, New York's wetlands have been reduced overall by 60 percent[170] and some individual wetland types more so. Historically, most wetlands were lost to agriculture, but today development is the primary cause in most regions of the state[171]. Marl pond shores and marl fens, two communities dominated by sedges, rushes and other plants that occur on marl deposits (mixtures of clay, carbonates of calcium and magnesium and shell remnants), have lost more than 90 percent of their area[172], leaving less than 100 acres of each[173]. Other losses include between 70 to 90 percent of the following: coastal plain poor fens, inland Atlantic white cedar swamp, freshwater tidal swamp, inland salt marsh, patterned peatland, perched bog, pitch pine-blueberry peat swamp, rich graminoid fens, rich sloping fens and riverside ice meadow (a community found along rivers where winter ice scours away woody vegetation, leaving the banks clear for rushes, sedges, grasses, sweet-gale, silky dogwood and rose pogonia)[174]. Brackish intertidal mudflats and shores, found primarily along the 150-mile Hudson River estuary and the Long Island shore, have been reduced between 50 to 70 percent, as have streams and ponds on the coastal plain[175].

Another group of much-reduced biotic communities are those associated with highly developed coastal areas, including some of the wetland types mentioned above. Long Island has lost 99.9 percent of its endemic Hempstead Plains grassland[176], along with 98 percent of its endemic maritime heathland[177]. Other coastal communities reduced by more than 90 percent are maritime oak-holly forest, maritime red cedar forest and coastal plain Atlantic white cedar swamp, heavily cut for making cedar shingles[178].

New York is rich in rare ecosystems that developed on various types of poor soils. Notable is the pine barren, characterized by sandy, dry, acidic soil. Major examples can be found on Long Island, near Albany and in the Saratoga County Sand Belt[179]. Pine barrens are in trouble wherever they survive in New York and neighboring states, primarily because of suburban sprawl, agriculture and fire suppression that causes replacement of the characteristic pitch pine and oaks by ubiquitous northern hardwoods. The Long Island pine barrens, now covering several hundred thousand acres on eastern Long Island, have been reduced by 60 percent[180]. These barrens contain unique plant communities such as pitch pine-oak forest, pitch pine-oak heath woodland, dwarf pine barrens and in the wetter areas pine barrens shrub swamp and Atlantic white cedar swamp[181]. The heath hen, driven to extinction in the 1930s by market hunting and habitat loss, lived in the pine barrens[182], along with many other now rare animal species such as the federally listed piping plover and Hessel's hairstreak, a green butterfly that feeds as larva only on Atlantic white cedar[183]. The pine barrens buck moth, which feeds only on scrub oaks, is a candidate for endangered species listing because of diminution of pine barrens throughout its range[184]. Other rare poor-soil communities include serpentine barrens, 98 percent gone (42 acres remain)[185]; calcareous pavement, reduced approximately 80 percent[186] (some 2,000 acres remain); and alvar grasslands (approximately 115 acres remain, a 77 percent decline)[187]. These last are communities of grasses, sedges and other moisture-loving plants that occur on shallow, moist soils lying over flat outcrops of limestone or other calcareous bedrock.

Because New York has very few federal lands, habitat protection has been up to the state[188]. Compared with other states, New York has done a good job of protecting big areas, particularly forests. Adirondack Park, a partially protected area three times the size of Yellowstone National Park, provides habitat for rebounding populations of otters, beavers and minks[189].

Nonetheless, much more needs to be done. Eighty-eight animal species are listed by New York as endangered, threatened or of special concern, including the least tern, shortnose sturgeon, Karner blue butterfly, wood turtle, common barn owl, cricket frog and eastern bluebird[191]. Many of these species need better habitat protection to ensure their survival. In addition, reintroduction should be considered for some species extirpated from the state, such as golden eagles and cougars[192]. More should be done to protect the many smaller, unique ecosystems, such as the various types of fens, other wetlands and poor-soil communities such as the pine barrens. Action also needs to be taken against acid precipitation, which has killed all fish life in 200 higher elevation lakes in the Adirondacks[193] and causes serious damage to high-altitude forests[194]. An additional major threat without a clear solution is the explosion of exotic species such as the Dutch elm fungus and the scale insect vector for beech bark disease[195]. This problem is severe; for example, the hemlock wooly adelgid, an aphid-like pest, can virtually extirpate hemlock from an infected forest[196].

IOWA

LOSSES

- Total reduction in wild ecosystems: 95 percent
- Tallgrass prairie reduced 99.9 percent
- Wetlands, all types, reduced 89 percent
- Prairie potholes (wetland type) reduced 95 percent
- Fens (wetland type) reduced 65 to 77 percent

Iowa

Iowa is an example of a state that has lost most of its natural vegetation and wildlife. Only five percent of the original 40 million acres[197] of natural prairie, forest and wetland remains, much of it in degraded condition. Virtually no public land in Iowa was set aside for preservation during the period of European settlement in the 1800s[198]. Nor did the state or federal government subsequently purchase extensive private lands for conservation (only an estimated 2,000 acres of prairie were protected by the state in 1900[199]). As a result, many ecosystem types exist today only as tiny patches primarily on lands purchased since the 1930s by the state, universities and private conservation organizations[200].

At the time of European settlement, most of Iowa, some 30 million acres, was covered by tallgrass prairie[201]. The prairies supported an abundance of bison, elk, waterfowl and other animals with a deep, rich soil produced by decomposition of prairie plants over thousands of years. Ironically, when Iowa was first settled in the early 1800s, homesteaders believed the prairie soils were poor because of the lack of trees[202]. Actually, forests were excluded from the prairie by a combination of low rainfall and periodic fires, not by poor soil. Once the invention of the John Deere plow allowed the heavy prairie sod to be broken easily[203], Iowa's soil was found to rank with the richest in the world. Immigrants rushed to establish farms, and by the time of the Civil War much of the agriculturally desirable moist prairie had been converted to crops and pasture[204]. By 1920 most of the less desirable wet prairie had also been drained and plowed[205]. Tiny remnants survived in boggy areas, on railroad rights of way and in other areas where access or cultivation was difficult[206].

The enthusiasm with which farmers converted the native prairies to other uses was so great that today, despite scattered restoration efforts begun in the 1930s[207], 99.9 percent of the original tallgrass prairie is gone[208]. Lumping all types of Iowa prairie together, including tallgrass, hill prairies, loess hills and sand prairies, less than 10,000 acres remains[209]. The tallgrass prairie, once by far the most abundant prairie type, is now rarer than many of the other types that had the good fortune, like sand prairies, to be associated with soils too poor for agriculture.

At the same time the prairie was being plowed, Iowa's forests were cleared for building materials and fuel, and wetlands were drained. At the time of European settlement, forests occupied somewhere between 12 and 19 percent[210] of the state. Today, these woodlands cover only about four percent of the state[211], and an additional net loss of 6,900 acres occurs every year[212]. The original 4 million acres of wetlands has been reduced by 89 percent[213], and only 26,000 acres of what remains is natural marsh[214] (most is rivers, lakes, reservoirs and farm ponds). Fens — small, boggy, spring-fed wetlands[215] — are species-rich ecosystems containing at least 200[216] of Iowa's 1,500[217] plant species, including several that are officially endangered, threatened or of special concern. Draining has reduced fens by between 65 and 77 percent[218], and most of what remains is on private land and therefore relatively unprotected[219].

This dramatic conversion of the land base to agriculture has deprived many species of the habitat they need to survive. Seventy native plant and animal species have been lost from the state[220], including the wolf, mountain lion, bison, elk, trumpeter swan, greater prairie chicken, sandhill crane and long-billed curlew[221]. More than 200 plants and animals are on the state list of threatened and endangered species including the bobcat, pallid sturgeon, silky prairie clover and bog birch[222]. The Cooper's hawk has become endangered through loss of interior forest habitat[223]. Piping plovers and interior least terns are endangered because of flood control measures[224] that prevent formation of the sand bars they need for nesting. Least terns now nest in only two places in Iowa, both artificial islands made of fly-ash debris from power plants[225]. Even some plants, which typically require less habitat than animals to sustain themselves, are in trouble. For example, the western prairie fringed orchid, a federally threatened species occurring in moist prairies, is found on only 15 sites in Iowa[226]. Many of these sites are so small that they cannot support enough orchids to attract pollinating insects, with the result that orchid reproduction is poor[227].

Iowa state agencies and private groups are attempting to preserve ecosystem remnants as well as to restore destroyed or degraded sites. At least 25 small prairie reserves ranging from three to 240 acres are protected by the State Preserves Advisory Board, the Iowa Conservation Commission and The Nature Conservancy[228]. The Iowa Prairie Pothole Joint Venture, run by the Department of Natural Resources, purchases wetlands outright and also works with private landowners to protect them. The program's goal is to protect 2,700 acres of wetlands and associated uplands each year. In 1993 the Joint Venture bought 236 acres of wetlands and acquired conservation easements on an additional 353 acres[229]. The Iowa Department of Natural Resources has attempted to reintroduce a number of extirpated or reduced native species, with some notable successes such as the wild turkey[230]. Unfortunately, such good efforts are dwarfed by the magnitude of the ecological destruction that has already taken place. Much more ambitious protection and restoration efforts will be necessary to raise the acreage of imperiled ecosystems and numbers of endangered species to levels where they can be considered secure.

SECTION FOUR

Recommendations

The growing peril of our nation's natural ecosystems demands a forceful response, but solutions are challenged by the scale of the problem. Millions of acres of natural ecosystems are endangered in all parts of the United States. Responsibility for conservation is cross-jurisdictional, resting with hundreds of federal, state and local agencies. Many of the threats are to private lands where protection options are limited.

The human activities that are causing ecosystem loss — agriculture, dam and road construction, logging, other resource use and residential development — are so much a part of our traditional way of life that it is difficult to think about how to moderate them. It is not easy for the world's wealthiest country to acknowledge that we are no longer the sparsely populated frontier nation of an earlier century, with apparently limitless resources waiting to be exploited. But acknowledge this we must if calamitous loss is to be prevented. We must admit that there are limits to the resources our land can provide and must take a hard look at the tradeoffs. If we allow high levels of grazing on ecologically fragile lands, we may gain greater cattle production but lose western riparian ecosystems and the species dependent on them. If we allow logging on unstable slopes or too close to streams and rivers, we may gain in timber production but lose economically valuable salmon fisheries. In south Florida, we can have more residential sprawl and polluting sugarcane plantations, but we will lose the natural wonders of the Everglades and the Keys. In southern California, we can either build more houses and congested freeways or we can preserve the character and multiple species of coastal sage country.

The challenge is partly to find ways to make economic development less invasive, destructive and wasteful, and to ensure room for both humans and nature. Curbing excessive human population growth and its drain on resources should be a top priority, but even if we are not fully successful much can be done to reduce the impacts of economic development on ecosystems and thereby improve the quality of life for us and our descendants. We can learn to conserve, recycle and reuse natural resources such as wood products. We can restructure government subsidies to discourage environmentally destructive methods of ranching, farming and logging and promote methods that are beneficial. We can pass zoning ordinances to slow sprawl and promote more intimate communities where neighbors live closer together. We can try to direct further development to lands that already have been ecologically degraded and away from the last unspoiled natural landscapes.

Making such fundamental changes will require action by government on all levels, as well as by industry, developers, scientific institutions, philanthropic foundations, conservation organizations and individual citizens. Because most land-use decisions are made by local government, local efforts to protect natural areas can have tremendous cumulative impact. State and federal initiatives can focus on large-scale patterns of land and resource use, economic incentives and coordinated scientific programs.

Here we recommend some actions that need to be taken. These are not detailed recommendations but rather suggested overall goals for a national conservation effort.

- **Make Ecosystem Conservation a National Goal.** We must make ecosystem conservation a national goal given high priority at all levels of government and in all sectors of society. Collectively, we must increase public awareness of the need for ecosystem conservation, provide more resources and better coordination for planning and implementation of conservation measures, and ensure adequate laws to protect ecosystems.

On the federal level, although many laws and programs indirectly contribute to ecosystem conservation, at present there is no law or national policy addressing conservation of ecosystems. We urgently need legislation or other federal action that can provide adequate recognition and funding for ecosystem conservation and ensure, for example, that ecosystem protection is a land management priority.

There are past successes to turn to as good examples of legislation targeted to help specific parts of the environment. The Clean Water Act has protected wetlands and resurrected many dying rivers, including the Potomac River which supports one of the nation's premier largemouth bass sport fisheries. The Clean Air Act has brought cleaner air to some cities. And the Marine Mammal Protection Act has helped restore many once-imperiled species, including the elephant seal and sea otter.

One important area where a new emphasis on ecosystem conservation could have a major impact is land purchase. Local, state and federal governments and private land trusts buy millions of dollars worth of land every year for recreation, open space, and other purposes. Ecosystem protection should be given greater consideration in these purchases.

• **Maintain and Strengthen Existing Environmental Laws.** One of the most urgent needs is to stop members of the 104th Congress from undermining environmental laws such as the National Forest Management Act, the Clean Air Act, the Clean Water Act and the Endangered Species Act, which a least provide some protection for ecosystems. The Clean Air Act, for example, helps decrease ozone pollution in the lower atmosphere, which damages pine forests and chaparral in California. The National Forest Management Act helps to "provide for diversity of plant and animal communities" in federal forests.

By protecting the habitats of species listed by the federal government as threatened or endangered, the Endangered Species Act protects ecosystems. The act prohibits "taking" of listed species, which the courts have interpreted as barring both direct killing and habitat destruction. The act also provides for designation and protection of "critical habitat," that is, habitat essential to the survival of the species[231]. For economic and political reasons, however, critical habitat is rarely designated. A recent development that may help endangered ecosystems is that the U.S. Fish and Wildlife Service, which is primarily responsible for implementing the Endangered Species Act, has begun to simultaneously list species that share the same habitat. This makes it more likely that the endangered ecosystems in which these species occur may be listed as critical habitat or otherwise receive increased notice and protection.

Another legislative need is to strengthen the enabling legislation for the National Wildlife Refuge System. Despite its name, present legislation establishing the system fails to establish ecosystem conservation as a primary purpose, leaving refuges vulnerable to mining, livestock grazing and other secondary uses that can threaten wildlife and ecosystems.

• **Reform Policies that Harm Ecosystems.** We should end or reform government subsidies that support resource use harmful to natural ecosystems. One target for reform is the General Mining Law of 1872, which allows anyone to take ownership of ore-bearing land in national forests or on other federal lands for as little as two dollars and fifty cents an acre[232]. Under the law, mining generally takes precedence over other uses on public lands, except on those — like national parks and Indian reservations — that have been specifically withdrawn from mining[233]. This makes it difficult to protect biologically important lands that do not fall into a category specifically exempted from mining. There are many other opportunities for reform: we can restrict timber sales — particularly those that cost the federal government money — in ecologically sensitive areas. We can reduce livestock densities on ecologically degraded or fragile lands and raise grazing fees on federal land to market levels. And we can halt or decrease federal subsidies for agricultural commodities like corn and soybeans that have spawned vast corporate farms with economic incentive to convert every wetland and hedgerow to crop production.

Although our national network of public and private conservation areas should be enlarged and strengthened, for financial and political reasons it will be impossible to set aside lands adequate to protect all U.S. ecosystems. If many natural ecosystems are to survive, they will have to do so on private and public lands that are also used by people. We must employ creative systems of incentives, voluntary programs, collaborative ventures, education and other means to help people safeguard the natural ecosystems in which they live. Incentives include deferring estate taxes for lands managed for endangered species or ecosystem conservation, allowing tax deductions and credits for conservation expenses, and expanding farm conservation programs such as the Conservation Reserve Program* and redirecting them to focus more on ecosystem conservation.

- **Improve Scientific Knowledge About Ecosystems.** We need more scientific knowledge about ecosystems in order to develop adequate plans for their protection. Lack of ecological understanding is one reason so many past and present land management policies, like the disastrous federal fire suppression policy of the past 50 years, have contributed to ecosystem endangerment.

A high priority is to adopt a consistent, comprehensive national system of identification and nomenclature for ecosystems, vegetation types and the like. This will facilitate data sharing and collaboration and provide a national checklist of ecosystems for evaluation and protection.

In order to make conservation plans, we need to know the status and location of ecosystems. Therefore, all U.S. ecosystems should be mapped and assessed in terms of quality and condition, with particular attention to those that are rare or that have been greatly degraded or reduced in area. The National Biological Service, in cooperation with many states, has undertaken state "gap" analyses** to identify ecosystems that are not adequately protected by the existing network of public and private conservation areas or by other conservation mechanisms. This survey needs to be completed for the entire nation.

We need to expand existing ecological research on how ecosystems function and to identify key species and/or ecological elements necessary to sustain them. One pressing scientific need is to develop a method to predict how much an ecosystem can be reduced and still be viable in the long term. At some point an

* The federal Conservation Reserve Program enrolls farmers who agree to withdraw land from agricultural production in exchange for an annual rental payment plus cost-sharing in planting a permanent, soil-conserving ground cover. Roughly 36.4 million acres have been enrolled in ten-year contracts at a cost of $1.6 billion per year since the program began in 1986. Although the program's original purpose was soil conservation, midwestern waterfowl and other wildlife have benefitted tremendously (*The New York Times*, January 10, 1995, page C4).

** See footnote, page 5.

ecosystem can be so reduced that the remaining fragments are doomed to eventual disintegration.

A national endeavor of this magnitude needs a central agency to provide leadership, help set priorities, ensure data compatibility, facilitate cooperation among partners, undertake national assessments and provide funding. We therefore need a robust National Biological Service or analogous national agency with adequate technical capability and funding. Substantial support and direction also could be provided by the proposed National Institute for the Environment, a proposed multidisciplinary research agency with the mission of focusing a broad spectrum of scientific research on applied environmental problems. In addition, existing research programs of federal agencies, such as the Forest Service's Research Program, should be given additional funding by Congress.

- **Develop Management Plans for Whole Ecosystems.** Rapid scientific advances in conservation biology during the last 30 years have revolutionized our understanding of what is necessary for long-term survival of both species and ecosystems. We know that removal of keystone species* like prairie dogs or pollinating bats can cause harmful effects that ripple through entire ecosystems, causing further extinctions and deterioration of the ecosystem fabric. We know that chainsawing a forest into fragments will benefit cowbirds and white-tailed deer but harm wood thrushes and woodland caribou.

These lessons have taught us that ecosystems cannot be managed as isolated pieces. If a herd of caribou migrates 500 miles between its calving and wintering grounds, management must consider the caribous' needs in both places and in between. If silt from a logging site clouds a river miles away and kills incubating salmon eggs, the river and the forest must be managed together. The large scale of these ecological interactions requires that all landowners and land management agencies with jurisdiction over an ecosystem collaborate in order to be effective. This approach is called "ecosystem management." Such partnership programs can be unwieldy, given the number of potentially involved parties. California's Natural Communities Conservation Planning program involves the California Department of Fish and Game, conservationists, 35 private developers and more than 30 cities**. But there is no alternative.

* Keystone species play such central roles in their ecosystems that the survival of many other species depends on them. Flying foxes are large tropical bats largely or solely responsible for pollinating and dispersing the seeds of hundreds of species of tropical plants, many of great economic importance (R.B. Primack, pages 44-45). Prairie dogs are keystone species in the shortgrass prairies of the West where they improve soil quality, provide essential food for the endangered black-footed ferret and other species, and share their burrows with burrowing owls and other species (*The New York Times*, July 11, 1995, page C1.)

** California's Natural Communities Conservation Planning program (NCCP) was launched in 1992. This voluntary program allows developers to destroy a limited amount of coastal sage scrub in return for their cooperation in the protection of the most important expanses. However, because most of the remaining scrub is on private land that can be worth millions of dollars an acre, and because the funding mechanisms for establishing any potential reserves are not decided, the outlook for the plan is not clear (R.B. Taylor, pages 26-33).

Because the ecosystems we are trying to manage are so complex, federal and state agencies and other managers should base their plans on the best available scientific information, theories and techniques. These should include identification of rare or threatened ecosystems, consideration of disturbance regimes*, calculation of minimum viable population sizes for key species** and proper use of indicator species†.

Using good science is more crucial than ever because many ecosystems are in such poor shape that there is little margin for management error. Moreover, many ecosystems are now so degraded that they need our careful intervention in order to survive. For example, prescribed burning will have to replace natural fires that no longer occur and herbivore control or reintroduction of predators will be necessary in places where natural predators are missing.

Because ecological systems are so complex and in many cases exceed our ability to understand them completely, management must always be undertaken with the understanding that outcomes may vary from those predicted. Therefore, continuous monitoring of changes in each managed ecosystem is essential in order to correct faulty management in mid-course or respond to changing conditions. This step-by-step process of management, monitoring, corrected management and more monitoring is called "adaptive management."

Finally, land management by federal and state agencies must reflect the national goal of ecosystem conservation by giving survival of natural ecosystems high priority. Reaching the point where agencies are willing to curb logging, livestock grazing, dam-building and other potentially harmful activities will require education for agency employees, incentives to reward employees for successful conservation activities, and changes in the existing laws that too easily encourage these destructive practices.

Conclusions

Many environmentalists shy away from the idea of ecosystem conservation because it seems difficult to sell to the general public and to policy makers. Ecosystems are less tangible than species, and certainly less charismatic. To most people, an alkaline fen does not have the charm of a baby seal, a scrap of desert sagebrush land cannot compete with an eagle or mountain lion. Therefore, at a time when some political leaders are calling for drastic weakening of the Endangered Species Act, how can we persuade them to expand protection beyond species to ecosystems?

* A disturbance regime is the specific type, size and frequency of disturbance that occurs in an ecosystem. In longleaf pine forests the historical disturbance regime was characterized by frequent, low intensity fires, covering large areas.

** A minimum viable population size (MVP) is the minimum number of individuals necessary to ensure that a population survives over some specific period of time, given known causes of mortality, genetic characteristics, demographic makeup, and other factors. MVPs generally considered necessary for long-term survival of large mammals are in the range of 500 to 1,000 individuals.

† An indicator species is used by managers to indicate the condition of other species or even an entire ecosystem. Sensitive predators at the top of the food chain, such as ospreys, are often good indicators of pollution problems.

First, we must educate people so they understand that the survival of wildlife depends on protection of healthy natural habitats. We can also offer the compelling argument that ecosystem conservation is more efficient and cost-effective than single-species conservation and, if done right, will likely prevent many species from being put on the endangered species list, which will save money.

Further, many of the actions that are destroying ecosystems — below-cost timber sales, livestock grazing on desert lands, farming on marginal lands — are wasteful of natural resources and would not be economically feasible without federal subsidies.

We believe that ecosystem conservation is urgently needed. The extensive degradation and loss of natural ecosystems in the United States is well-documented. These trends continue with every new shopping center, every new highway, every new clearcut. They occur when sediments from farmlands wash into streams, when waters are diverted, when fires are suppressed and when other ecological processes are disrupted. Nothing short of a national commitment is needed to turn these trends around. That commitment has to start with recognition of what we have already lost and what we will lose in the near future without concerted action. We have the necessary scientific tools to do the job — the last few decades have seen scientific breakthroughs in our understanding of how ecosystems work and of the basic habitat requirements necessary for species to survive. As a nation, we need to develop a heightened sense of ethical obligation to future generations and other species and the will to change. We must protect species and ecosystems before the opportunity to do so is lost forever.

APPENDIX A

Threats to U.S. Ecosystems

Presently, the most deleterious threats to ecosystems are habitat destruction, invasions of non-native (exotic) species, fire suppression, recreation and environmental toxins. Over the next few decades another threat may prove as harmful as any of the others — global climate change. Hunting can also be a problem if poorly regulated, but is not now a major threat to most species in the United States.

Habitat Destruction

Here we use the term habitat destruction to describe human activities that directly alter the structure of a natural habitat so as to decrease its ability to support many or most of the native species living there. Thus habitat destruction includes intensive agriculture, clearcut logging, roadbuilding, housing and other development, and damming and channelization of streams. Heavy grazing by livestock also qualifies in many cases. The effects of farming, grazing or logging may be temporary if these activities are abandoned and the land is allowed to heal through natural succession. On the other hand, urban development is more permanent as are most highways and dams. The most severe habitat destruction occurs with long-term conversion of a natural ecosystem to an artificial system, as when a riparian forest is replaced by a shopping mall.

The overwhelming consensus among conservation biologists is that direct habitat destruction is the greatest threat to biodiversity at both the species and ecosystem levels[234]. When vital habitat is substantially altered, a population decline is virtually inevitable. If the population has already been reduced by hunting or other reasons, recovery may be impossible. At some point the population becomes too small and fragmented to persist. If a species is narrowly restricted to a small area, as is the case for many endemic plants and for animals such as desert fish restricted to single spring, even limited development can spell extinction. When a habitat is altered so severely that many species decline and are replaced by more tolerant species or by a desolate environment that supports virtually no life, then a natural community or ecosystem has been lost.

According to recent studies, habitat destruction is the major factor threatening 80 percent or more of the species listed under the federal Endangered Species Act. More than 95 percent of listed species are imperiled at least in part by habitat loss or alteration[235]. Habitat destruction was a contributing factor in the extinction of at least 73 percent of 27 species and 13 subspecies of freshwater fishes in North America over the last century and is the leading threat to the fish species now considered threatened, endangered or of special concern[236].

Among the activities responsible for habitat destruction, agricultural development generally ranks first. For example, nearly 90 percent of recent wetland losses are attributable to agriculture[237]. However, a review of recovery plans for endangered and threatened plants identified urban development as the greatest threat to the habitats of these plants[238].

In less developed regions of the country such as rural areas of the Northeast, Rocky Mountains, Southwest, Intermountain West and Pacific Northwest, commodity production activities such as logging, mining and livestock grazing are the major threats to endangered species and ecosystems. For example, grazing has been identified as a contributor to the decline of more than 340 species listed or candidates for listing under the Endangered Species Act[239]. Loggers have cut more than 90 percent of the ancient forest of the Pacific Northwest, home to the northern spotted owl, marbled murrelet and many other rare species[240]. Dams, logging, road-building and livestock grazing are the major factors in the decline of salmon in the Northwest[241]. Road-building for logging, oil and gas exploration and other resource extraction activities in the northern Rocky Mountains makes wild lands accessible to poachers and is the major obstacle to recovery of the grizzly bear in the Lower 48[242]. Particularly in the West, most of these activities occur on public lands, often with a net cost to the taxpayers when additional federal dollars must be spent in an attempt to recover populations of wildlife species harmed by the very same activities. In all these cases, as native species decline the integrity of the ecosystem also declines. This is true especially for keystone species such as salmonids and large carnivores that have controlling influences on ecosystems[243].

Invasions of Non-Native Species

After habitat destruction, invasion of non-native species (also called exotic or alien species) is the greatest threat to rare native species and to the integrity of ecosystems[244]. The two threats often occur in tandem, because a disturbed habitat is more readily invaded by exotic plants. For example, heavy livestock grazing in the Intermountain West has led to a major reduction in the cover of native perennial bunchgrasses[245]. Disturbed shrub-steppe communities are then rapidly invaded by exotics, especially cheatgrass, a

Eurasian annual that probably arrived on this continent in contaminated grain[246]. In the Florida Everglades, the Australian melaleuca tree invades most readily after people have diverted water, leaving the marshes to dry and burn. Similar histories have been played out across North America — disturbance by farming, grazing, logging, roadbuilding or development, followed by invasion by non-natives, negative interactions with native species and alteration of ecosystem processes such as disturbance regimes and nutrient cycling. Over half of federally listed species are affected adversely by interactions with non-native species[247]. Many North American natural communities overrun by exotics now look more like European, Asian or Australian communities.

Hawaii, California and Florida have perhaps the most severe problems with exotic species of any of the states. In Hawaii, both the Polynesians and Europeans introduced exotic species of plants and animals. These introduced species are now considered the single greatest cause of extinction of Hawaii's native fauna and flora[248]. Introduced predators such as cats and rats have caused sharp declines in the populations of native birds and insects, while rooting and grazing by feral pigs and goats have damaged native plants and facilitated the spread of exotic grasses and weeds. Introduced European grasses have altered the structure of California's fragile coastal dune communities and invaded almost all remaining valley grasslands. As in Hawaii, the ecological impact of these exotic species has been exacerbated by grazing by imported livestock. In Florida the intentionally introduced melaleuca, Brazilian pepper and Australian pine now dominate many land areas, while the exotic hydrilla and water hyacinth have altered many aquatic communities by outcompeting native species and changing water chemistry[249]. (See the Florida, California, and Hawaii case studies beginning on page 24.)

Thus both the physical habitats and the biotic communities that make up ecosystems can be severely altered by exotics. A frightening example is the zebra mussel, a filter-feeding Eurasian bivalve that became established in the Great Lakes around 1985, probably carried there in ship ballast water. Zebra mussels have spread into all five lakes and many rivers and other lakes in the East, competing with native species for food and space and altering entire food webs. Biologists predict that the rapidly reproducing mussel will eventually inhabit most lakes of temperate North America with adverse long-term effects on community structure and ecosystem function[250].

Many introductions of plants and animals into U.S. ecosystems were intentional. State wildlife agencies introduced game birds such as the ring-necked pheasant (originally from China) and game fish from other continents or from outside their native range on this continent. These introductions have widespread ramifications, especially in aquatic habitats. At least 70 non-native fish species and 158 fish species transplanted outside their native range in North America have become established at new locations[251]. Many naturally fishless high mountain lakes in the Rocky Mountains, Sierra Nevada and Cascades have had trout introduced and are no longer suitable breeding areas for amphibians[252]. The opossum shrimp was introduced in Flathead Lake in Montana and in other lakes and reservoirs in the West to provide an extra food source for economically important salmon. But the shrimp was such a successful predator of small crustaceans called cladocerans — a primary food for salmon — that the salmon fishery collapsed, adversely affecting tourism. Bald eagles and grizzly bears, which eat salmon, also were adversely affected[253].

Fire Suppression

Ecosystems are distinguished as much by their processes as by their species composition and structure. When natural processes are disrupted, the vegetation or habitat structure of an ecosystem can change radically, often beyond the ability of native species to adapt. Among the processes most important to the maintenance of biodiversity are natural disturbances such as fire, flood and wind. We concentrate here on fire because the terrestrial ecosystems of North America have been shaped as much by fire as by any other factor and because suppression of natural fires has led to dramatic changes in vegetation structure and declines of many plant and animal species associated with fire-maintained vegetation. Many of our most endangered ecosystems —grasslands, savannas, barrens, open forests such as longleaf pine and ponderosa pine — have declined largely as a consequence of fire suppression[254].

Fires were common in North America prior to European settlement, in some areas burning as often as every year or two. In many cases these fires were ignited by lightning. Thunderstorm frequency on the southeastern coastal plain, for example, is more than enough to account for the dominance of the region by longleaf pine and other fire-dependent vegetation when the Europeans first arrived. In other cases, fires set by Indians maintained characteristic natural communities such as the prairies and oak savannas of Oregon's Willamette Valley. Because Indians apparently used fire to manage vegetation for thousands of years, many plant and animal species adapted to these fire-maintained habitats. Thus Indian fire should be considered as natural as lightning fire. The European settlers, however, did not understand the beneficial effects of fires and actively suppressed them. The legacy of their ignorance remains as shown by Smokey the Bear advertising in national forests and by the media's exaggerated response to the Yellowstone fires of 1988. Roads, clearcuts, agricultural fields and urban areas have served as firebreaks, stopping fires that once would have burned hundreds or even thousands of square miles.

When fires are suppressed either actively or passively, the natural community may change radically, sometimes over the course of only a few years. Fire-sensitive species such as hardwood trees and shrubs, restricted to sites naturally protected from fire such as steep ravines, lakeshores and islands, invade and often outcompete fire-adapted species. The density of tree and shrub stems increases dramatically after years without fire, increasing the susceptibility of these plants to drought. Dense litter or duff accumulates and along with the greater abundance of woody fuels makes forests more vulnerable to catastrophic wildfire. Prairies and open fens are replaced by thickets. Grassland birds and other animals are replaced by shrubland and forest animals. The endangered red-cockaded woodpecker, an indicator of a healthy, well-burned longleaf pine forest, abandons its colonies when trees become crowded after a decade or so without fire[255].

Recreation

Probably the most harmful form of outdoor recreation is the use of off-road vehicles. Trail bikes (motorcycles), all-terrain vehicles (ATVs), four-wheel drive trucks, snowmobiles and other motorized vehicles now invade many wild areas once inaccessible to people. The effects are often devastating: accelerated soil compaction and erosion, pollution of water and air, noise, destruction of vegetation, direct harassment of wild animals and loss of wildlife habitat. The proliferation of mountain bikes in many regions has turned narrow footpaths into wide, eroding gullies that carry mud into streams. In arid lands, even a single pass of an off-road vehicle can destroy the delicate mats of lichens and algae that form a thin crust over the soil. Animals may be frightened away from water, food or shelter and small animals may be crushed[256].

Even hikers or horses can compact soil and increase erosion. Manure from horses or other pack stock often contains the seeds of exotic plants, which invade natural areas, especially areas disturbed by trampling. Hikers' pant legs carry their share of seeds (burs) from exotic plants.

Recreationists often want roads to provide access to ski areas and for hiking, hunting or fishing. But roads can provide access to poachers, fragment natural habitats, impede movement of small native animals, serve as avenues for the invasion of exotic plants and animals and accelerate erosion that clogs streams and destroys fisheries. Animal road kills are alarmingly high in many regions[257].

Environmental Toxins

Toxins known to damage ecosystem health include sulfur compounds, ozone, pesticides and heavy metals. Airborne pollutants such as ozone and acid precipitation often affect natural communities hundreds of miles away from the source[258]. For example, pollution from Los Angeles has traveled 190 miles eastward across the Mojave Desert to the Colorado River[259]. Acid rain and acid fog bathe many northeastern forests for thousands of hours each year, damaging vegetation and disrupting nutrient cycles by leaching calcium, magnesium and potassium from the soil while elevating aluminum concentrations[260]. In addition, the acid levels in some northeastern lakes and streams are high enough to kill amphibian larvae and fish, leaving some lakes without vertebrate life[261].

Ponderosa and Jeffrey pines in the San Bernardino Mountains bordering the Riverside-San Bernardino Basin in southern California have been heavily damaged by ozone produced primarily by motor vehicles[262]. In high concentrations, ozone can damage the needles of pine trees, resulting in premature needle senescence, impaired photosynthesis, reduced carbohydrate production and slowed growth[263]. In addition, ozone-damaged trees are more susceptible to other environmental stresses such as insect attack, root rot and winter frost[264]. In addition to harming Jeffrey and ponderosa pines, ozone explosure has been implicated in declines of eastern white pines, red spruce, Fraser fir, yellow pine, beech and sugar maple. Ozone-induced plant mortality can substantially alter the composition of an ecosystem. In California, for example, ozone damage inhibits the recovery of sage communities, which facilitates the invasion of exotic species[265].

Animals have been affected by anthropogenic chemicals that alter physiological processes. Many flagship endangered species — the bald eagle, peregrine falcon and brown pelican in parts of its range — were imperiled largely because of reproductive failures linked to widespread use of DDT and other organochloride pesticides. With regulatory control of these pesticides, populations of eagles, peregrines and other affected species have risen. However, other chemicals that mimic estrogen, a naturally occurring hormone, are interfering with reproductive ability in many species and have been linked to reproductive disorders and deformities in fish, birds, turtles and mammals in the Great Lakes region[266]. They also have been implicated in the decline of the Florida panther and some populations of the American alligator[267]. Hormonal activity of environmental toxins is especially troubling because it occurs at very low concentrations, often far below the levels at which cancerous tumors, the basis of standards set by the Environmental Protection Agency, would form[268]. Common industrial substances known to interfere with wild animal immune systems include benzene, dioxin and some pesticides and metals[269].

Other toxic byproducts of industrial activity include lead, cadmium, arsenic and mercury, all of which are poisonous even in minute amounts to the central nervous systems of humans and other animals[270]. Present atmospheric levels of these chemicals are now many times their natural levels: arsenic is four times normal, cadmium 20 times and lead 300 times[271]. Despite a nationwide ban on lead shot, past accumulations continue to kill an estimated two to three percent of the nation's waterfowl every year[272]. Although the harmful effects of these and some other chemicals have been identified, the majority of industrial chemicals remain unstudied. There is no information on possible toxic effects for 80 percent of the estimated 50,000 industrial chemicals produced in this country[273].

Global Climate Change

If climate change occurs as most climatologists predict, there will be dramatic changes in North American ecosystems. In some cases biological communities will shift location. In many cases they will fragment as the species that compose them become extinct or migrate[274].

These dramatic changes are likely because the warming predicted by scientists will be larger and faster than existing ecosystems have ever had to contend with. According to estimates by the National Academy of Sciences, the Intergovernmental Panel on Climate Change and other scientific organizations, the Earth's atmosphere is likely to rise by one degree centigrade, give or take 1.5 degrees, within the next 30 years. It could rise three degrees by the end of the next century[275]. The exact rate of warming will depend on many factors and could be slowed, for example, if people reduce use of fossil fuels.

We know from the fossil record and from computer modeling that a two- or three- degree climate change is enough to cause dramatic shifts in species ranges. For example, Margaret Davis of the University of Minnesota, has projected that a three-degree rise would shift the ranges of some common eastern deciduous trees, including sugar maples and beeches, to the north by some 1,000 miles[276]. This means they would die out over hundreds of thousands of square miles in what is today the southern portion of their ranges. So would many associated species of plants and animals. Scientists also project that other dominant trees will decline, including loblolly pines in the southeastern states, balsam firs in Minnesota, possibly many types of pines, spruce and firs in the mountains of western states and jack pines in Michigan[277]. The jack pines are essential to nesting of the endangered Kirtland's warblers. The entire population breeds exclusively in parts of three counties on Michigan's lower peninsula[278].

Because warming will be greatest at the higher latitudes, arctic tundra ecosystems are particularly at risk. Preliminary estimates are that tundra could be pushed as much as four degrees latitude toward the north, with more than 35 percent of it replaced by trees[279]. Throughout the world, sea level rise caused by global warming would erode and drown salt marshes and other coastal ecosystems[280].

Common ecosystems will face less risk from climate change than rare ones. Fifty years hence a rare ecosystem, such as the Monterey pine forest or a forested canebrake may be unable to persist where it is found today. This is one of the strongest arguments for restoring and expanding the extent of today's endangered ecosystems.

Individual species making up ecosystems will have greater risk of extinction if their ranges are small and fragmented. During periods of major climate change that occurred thousands of years ago, many species survived adverse conditions by moving hundreds of miles to find new homes where the climate was suitable. This solution will be more difficult under present conditions because cities, roads, dams, clearcuts and agricultural fields form barriers that will prevent many species from dispersing to colonize new areas[281]. Conservation biologists therefore advocate linking nature reserves and other natural areas with suitable dispersal corridors of natural vegetation.

Hunting and Harvesting

Historically, unregulated hunting was the major cause of species extinctions. In North America, the great auk, passenger pigeon, Carolina parakeet, Steller's sea cow, sea mink, Caribbean monk seal, buffalo wolf, plains grizzly bear and many other vertebrate species and subspecies were driven to extinction mainly by hunters. Today, however, in the United States laws restrict market hunting and regulate recreational and subsistence hunting and fishing, so fewer animals are threatened by direct killing by humans. Nonetheless, overharvesting remains a threat to some animals and plants, including bluefin tuna and certain sharks, and illegal hunting or trapping is a major threat to the survival of the grizzly bear and some other terrestrial carnivores[282]. The pet trade threatens many species of parrots and other tropical birds[283].

Quantitative and Qualitative Losses

How do habitat destruction, invasions of non-native species, fire suppression, recreation, environmental toxins and global climate change lead to losses and degradation of ecosystems? Degradation can be either quantitative, qualitative or both. Quantitative loss is outright destruction, as when a native prairie is converted to a cornfield or a free-flowing stream is dammed and replaced by a reservoir. In principle, quantitative losses can be measured easily by mapping changes in the amount of area covered by a specific type of ecosystem.

Qualitative losses, on the other hand, involve undesirable but often subtle changes in the structure, function or composition of an ecosystem. For example, a longleaf pine forest in which fire has been suppressed for several years gradually changes from a natural park-like condition to a dense thicket of young pines, oaks and other woody plants. A western grassland may be grazed so heavily by livestock that native perennial grasses are replaced by exotic annuals. Or a stream in an agricultural landscape may lose its trout or darters and become dominated by fishes typical of warmer, muddier and more sluggish waters. Many of the newly dominant fishes may be exotics.

One can express qualitative changes quantitatively, for instance by reporting that a certain proportion of grassland is overgrazed, but such estimates are usually less precise than for outright habitat destruction. In some cases, as when an ancient forest is converted to a tree farm, the qualitative changes are severe enough to be considered outright habitat loss. At some level of degradation, an ecosystem ceases to be "natural."

One of the more insidious patterns of ecosystem degradation is habitat fragmentation. Fragmentation involves both a loss of habitat area and division of the remaining habitat into smaller, more isolated pieces. Statistics on total acreage lost for a given natural ecosystem usually hide information on how that acreage is distributed. It may be all in one block. Or it may be distributed in a thousand tiny pieces.

When an ecosystem is fragmented, it often becomes poor habitat for the original inhabitants. Bears, cougars and other animals that require large home ranges will not survive habitat fragmentation unless they succeed in travelling between patches of remaining suitable habitat or are able to adapt to using the surrounding agricultural, residential or other disturbed land. Many species are not able to do either. Large carnivores, for example, are likely to be killed if they venture near farms or cities.

The outer zone of a habitat fragment is "edge habitat" with microclimate and vegetation strikingly different from the interior zone. For example, forest edges are sunnier, warmer, drier and windier than forest interiors. Many songbirds and other animals used to living in the deep interiors of forests, prairies or other ecosystems do poorly when forced to live next to habitat edges. Predation on birds' nests by raccoons, opossums and other opportunistic animals that thrive in fragmented landscapes is often more intense in edge habitat than the interior. Parasitism by brown-headed cowbirds, edge-loving birds that lay their eggs in the nests of other bird species, can be so intense in small forest or grassland fragments that many other birds are unable to raise their own young. The small populations of native species that remain in habitat fragments are often vulnerable to genetic deterioration and other problems associated with small population size and are unlikely to persist for long[284].

Fires and other disturbances cannot operate naturally in fragmented landscapes. Lightning fires, for instance, will occur very rarely in small patches of habitat if the surrounding landscape is agricultural land or other land types not conducive to fire. But when a fire does occur, it may completely consume a small patch of habitat, leaving no safe refuge for animals.

The result of these changes is that isolated ecosystem fragments lose ecological integrity — they do not function normally nor contain their characteristic plants and animals. Small patches of habitat not only contain different species than large ones, in most cases they contain fewer species because of what biologists call the species-area relationship. A 90 percent reduction in area typically cuts the number of species in half. As habitat size decreases, the first species to disappear are the edge-sensitive ones and animals requiring large home ranges.

Thus to be successful, an ecosystem conservation strategy must not only focus on the total size of all the remaining patches but also on the size, quality and spatial distribution of the individual patches. In most cases, successful conservation will require protection of patches large enough to allow persistence of natural patterns of fire and other disturbance and survival of species that require large ranges[285].

APPENDIX B

Descriptions of the 21 Most-Endangered Ecosystems

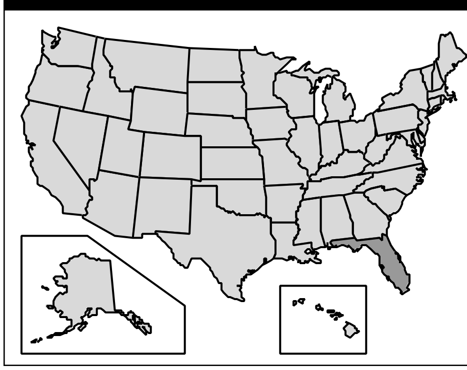
This appendix contains case studies for the 21 most-endangered ecosystems listed in Section 1. The maps accompanying the following ecosystem case studies do not illustrate the geographic extent of the ecosystems in question; they simply indicate states within which examples of the ecosystem type occurs. Unless otherwise cited, statistics describing the following ecosystems are from the National Biological Service (NBS)* report.

South Florida Landscape

The south Florida landscape ecosystem is a grab bag of interspersed habitats and plant communities that are all under tremendous pressure from development. The landscape includes both wetlands and uplands, among them the Everglades, pine rocklands, slash pine forest, tropical hardwood forests, estuarine and marine ecosystems of Florida Bay and offshore coral reefs. All of these communities are highly endangered.

Best known of the south Florida ecosystems is the Everglades, a giant expanse of marsh known as the "river of grass." The Everglades are covered by a slowly flowing sheet of water which originates in a chain of lakes just south of Orlando, nearly 200 miles north of Everglades National Park[286]. Excessive consumption of water for agriculture and residential purposes means that in some areas and some seasons there is too little water to sustain marsh life. At other times and places water mismanagement results in too much water. As a result, wading bird populations,

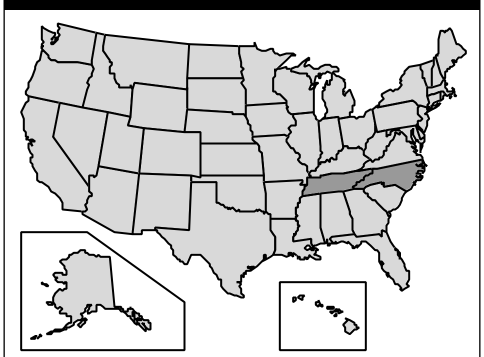
SOUTH FLORIDA LANDSCAPE



* The 1995 report entitled "Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation, by R.F. Noss, E.T. LaRoe III and J.M. Scott."

which reached 2.5 million birds during the last century[287], have declined by some 90 percent. An exotic Australian tree, the melaleuca, has displaced the diverse native flora in many parts of the Everglades and continues to spread at an alarming rate of 50 acres a day[288].

SOUTHERN APPALACHIAN SPRUCE-FIR FOREST



Even more endangered than the Everglades are the pine rocklands, rare subtropical upland communities which occur on often jagged outcroppings of Miami Rock Ridge limestones in south Florida and the central Keys[289]. The forest canopy and sub-canopy consists mainly of south Florida slash pine, silver and thatch palms, while the ground layer is primarily tropical shrubs. Lightning-ignited fires once swept through the rocklands every three to ten years, maintaining an open canopy of pines and preventing the tropical shrub understory from completely dominating all other plants. Over 98 percent of pine rockland habitat has been eliminated because of fire suppression and residential development near Miami and in the Keys. The remainder is threatened and degraded by fragmentation by roads and the invasion of the exotic Brazilian pepper.

The slash pine of southwestern Florida has declined by nearly 88 percent, and tropical hardwood hammocks have been reduced by an estimated 60 to 80 percent, mostly because of development. The estuarine and marine ecosystems of Florida Bay are collapsing as a result of human-caused changes in the quantity, timing and distribution of freshwater flows from the Everglades. Coral reefs also are threatened by these changes and by increased sedimentation from development along the coasts. As the south Florida landscape degrades, some of its characteristic wildlife — including the Florida panther, Key deer, wood stork, white-crowned pigeon, West Indian manatee and the green sea turtle — comes closer to extinction.

Southern Appalachian Spruce-Fir Forest

The dominant trees of southern Appalachian spruce-fir forests are red spruce and Fraser fir. Fraser fir stands occupy the highest peaks of the region, usually above 6,000 feet, grading into mixed fir and spruce at lower elevations. These forests are home to a number of rare and endemic species such as the spruce-fir moss spider and the rock gnome lichen.

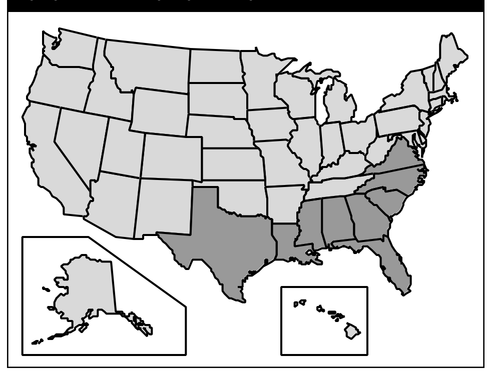
Fraser firs are being attacked by an exotic insect, the balsam wooly adelgid and possibly poisoned by acid fog drifting in from the adjacent Tennessee Valley. The result is so deadly to mature Fraser firs that well-developed stands are virtually nonexistent today. In their place are ghost forests of standing dead trees, tangled fallen logs and patches of dense young trees and shrubs[290]. Red spruce stands downslope from the Fraser fir are also declining, probably as a direct or indirect result of acid fog. The spruce-fir ecosystem is more threatened than the deciduous forest further down slope, something unusual in North America where high elevation ecosystems usually are in good shape because they escape most pressure from agriculture and development.

Longleaf Pine Forest and Savanna

At the time of European settlement, longleaf pine communities dominated more than 60 percent of the uplands on the southeastern coastal plain[291]. Most of the biodiversity of the longleaf pine ecosystem is situated in the ground layer, where a single stand might contain 200 species of plants, one of the highest diversities of herbaceous plants on Earth. This diversity was made possible largely by frequent lightning fires — every one to ten years, depending on the site — which kept any one species from outcompeting the others. Lightning strikes easily ignited in this system because longleaf pines drop highly combustible needles that mix with wiregrass and other grass species to create a highly flammable mixture.

The longleaf pine ecosystem is now highly endangered. Since European settlement, it has declined by over 98 percent on the southeastern coastal plain and by over 85 percent on the west Gulf coastal plain, having been replaced largely by tree farms and agriculture and by hardwood forests that invaded longleaf sites after the grass matrix was destroyed or fires were suppressed. Wiregrass, in particular, is virtually incapable of recolonizing a site from which it has been eliminated. Other plant communities embedded in the longleaf pine landscape, such as the amazingly species-rich pitcher plant bogs that occur in seepage areas along gentle slopes in the Florida Panhandle, southern Alabama and southern Mississippi, have declined as much as longleaf pine. Although collectively quite a few acres of longleaf pine remain across the Southeast, these sites are highly fragmented and degraded. Most sites lack many of the characteristic species of this ecosystem, such as the endangered red-cockaded woodpecker. Amazingly, some 27 federally listed species and 99 federal candidates are associated with longleaf pine and wiregrass in the Southeast[292]. Other animals in this group include the gopher tortoise, gopher frog, flatwoods

LONGLEAF PINE FOREST AND SAVANNA

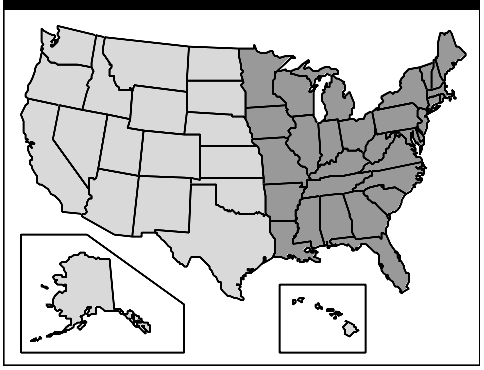


salamander, indigo snake, Bachman's sparrow and Sherman's fox squirrel.

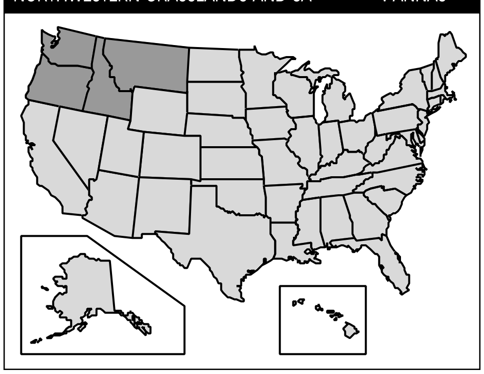
Eastern Grasslands, Savannas and Barrens

This category includes a wide variety of plant communities in the eastern, southern and midwestern states that are naturally treeless or contain individual trees that are widely spaced as open-canopied groves. They sustain many rare endemic species, among them the Tennessee coneflower, endangered Karner blue butterfly and loggerhead shrike.

EASTERN GRASSLANDS, SAVANNAS AND BARRENS



NORTHWESTERN GRASSLANDS AND SAVANNAS



Though we know that many of these communities have been shaped by a history of natural and introduced fire and have chemically unusual soils limiting tree growth, scientists are often unsure of the exact processes that led to their creation.

Agriculture, fire suppression and residential sprawl are major threats. Many of the more fertile savannas, including oak savannas across the Midwest, from Arkansas to Michigan, Wisconsin and Minnesota, have been destroyed by agriculture, with fire suppression degrading the remnants. Other extremely rare and reduced communities include the Hempstead Plains grasslands of Long Island; the calcareous glades — on high calcium soils — and cedar barrens of Tennessee, Louisiana and other southern and midwestern states; and the bluegrass savanna-woodlands of Kentucky[293]. More than 98 percent of barrens throughout the East and the great canebrakes of the Southeast have been destroyed. The remaining cane occurs mostly as an understory plant in forests or in thickets along fencerows. The serpentine and Pocono till barrens near Philadelphia and Baltimore are primarily threatened by residential development and roads that act as firebreaks[294].

Northwestern Grasslands and Savannas

Threatened by fire suppression, farming and development, the grasslands and savannas of the Pacific Northwest are faring little better than their eastern, southern and midwestern counterparts. Possibly dating back to the Pleistocene era, the northwestern grassland and savanna communities were shaped by periodic burning by Native Americans for thousands of years. Among the rare species associated with northwestern grasslands are Fender's blue butterfly and Bradshaw's lomatium — a yellow-flowered member of the parsley family — found only in the Willamette Valley of Oregon[295].

In the Willamette Valley and other interior valleys in western Oregon, some 99.9 percent of the native grasslands and oak savannas have been destroyed, primarily by agriculture. Another grassland, the great Palouse prairie of eastern Washington, northeastern Oregon and northwestern Idaho, formerly a vast expanse of native bluebunch wheatgrass, Idaho fescue and other grasses, is also virtually gone[296]. Only one tenth of one percent remains; most of the rest has been plowed and converted to wheat fields or is covered by cheatgrass and other exotic plant species.

The shrub steppe (high desert) of eastern Oregon, western Idaho and the northern Great Basin, was once a shifting mosaic of sagebrush and other shrub and grassland communities. Invasion by alien plants such as cheatgrass and medusahead, livestock grazing and disturbance of the natural fire patterns have destroyed nearly half of this community.

California Native Grasslands

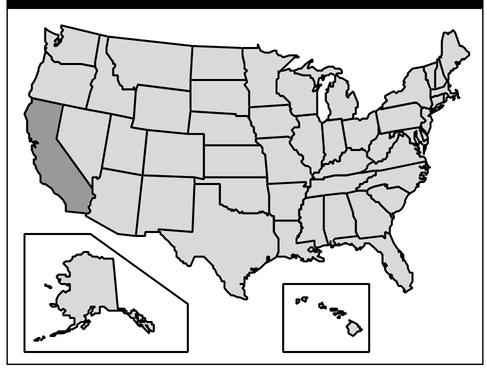
California was once covered by 22 million acres of native grassland, of which only one percent remains[297]. The rest have been lost to agriculture, urban development, livestock grazing, fire suppression and exotic species invasions. Specific losses include 99.9 percent of needlegrass steppe, 90 percent of northern coastal bunchgrass, and 94 percent of native grasslands in San Diego County.

Much of the area once covered by native grasslands has been taken over by exotic species. One source estimates an 8,653 percent increase in acreage covered by exotics since early surveys[298]. Tiny remnants of native grassland can be found on serpentine substrates where the unusual soil chemistry provides a refuge for native plant species better adapted than the invasive exotics. Native species dependent on grasslands have not fared well, including the endangered California condor, San Joaquin kit fox and California jewel flower.

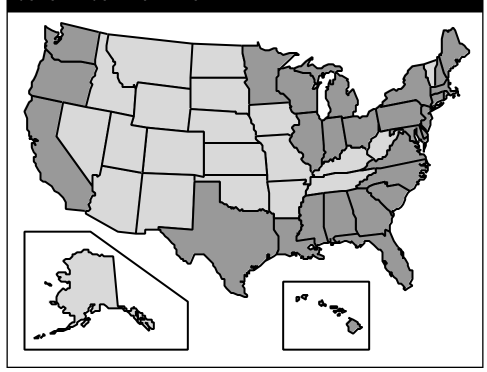
Coastal Communities in the Lower 48 States and Hawaii

Coastal communities are vulnerable because they are geographically restricted to narrow strips of habitat which are under intense human pressure. At least 80 percent of the coastline in the lower 48 states has been developed. What few wild shorelines remain are limited to a small part of Maine, the "Big Bend" coast of Florida (along the Gulf of Mexico where the peninsula meets the panhandle), the Olympic National Park section of the Olympic Peninsula of Washington and smaller stretches in other states. Similarly, the

CALIFORNIA NATIVE GRASSLANDS



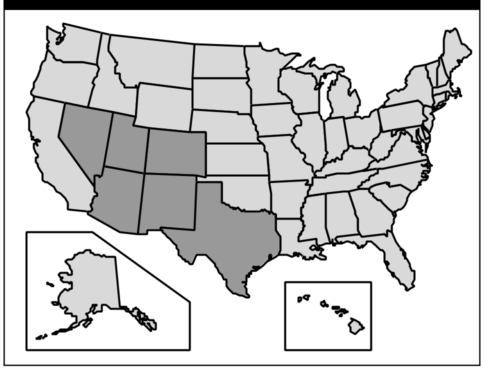
COASTAL COMMUNITIES



Great Lakes and other lakes have been heavily developed along much of their shores.

Overall, beach and coastal strand communities (occurring on dunes) are the rarest and most vulnerable. They sustain very high concentrations of endangered species, including several species of sea turtles, beach mice, and many localized plants. In Maryland, 95 percent of natural barrier island beaches and over 50 percent of dune habitats have been destroyed. A report on natural communities in San Diego County, California, concluded that the entire coastal strand had been lost[299].

SOUTHWESTERN RIPARIAN FORESTS



Over 98 percent of the maritime (coastal) heathland in New York and over 90 percent of this community in southern New England have been destroyed[300]. Estuarine and nearshore marine communities also have been heavily modified in most regions. The endangerment of Florida Bay and the Florida coral reefs is noted elsewhere. Other major losses include a 50 to 70 percent decline in brackish intertidal shores and mudflats in New York, a 90 percent loss of submerged aquatic vegetation in Chesapeake Bay, a 75 percent loss of seagrass meadows in Tampa Bay, Florida; a 93 percent loss of seagrass meadows in Galveston Bay, Texas, and an 80 percent loss of tidal marshes in San Francisco Bay[301].

Southwestern Riparian Forests

In the arid Southwest, river systems are ribbons of life, linear oases through landscapes that are hot and barren for much of the year. The rivers sustain riparian forests which are the most structurally diverse habitats in the region and are often the only areas outside the mountains that support trees. Cottonwoods, willows and other woody species growing along streams and rivers (many of them ephemeral, flowing for only part of the year) provide habitat for many species. Some 80 percent of all vertebrate species in Arizona and New Mexico depend on riparian areas for at least part of their life cycles and over half of these species cannot survive without access to riparian zones[302]. More than 100 state and federally listed species in Arizona and New Mexico are associated with riparian cottonwood/willow forests[303].

Unfortunately, these communities have declined by over 90 percent since European settlement[304]. The major cause of the decline has been livestock grazing. Cattle trample and remove vegetation from streambanks, leading to channel widening and downcutting; they pollute the water with their excrement; and they browse young willows and cottonwoods, preventing forest regeneration. Other threats to riparian areas include dam construction, water withdrawals for irrigation, conversion to agriculture or urban habitats and invasion by alien species. Perhaps the most troublesome invader is the aggressive tamarisk tree from the Middle East, which lowers the water table by transpiring huge amounts of water and is difficult to eradicate. Rare wildlife associated with southwestern riparian zones include such fish as the Gila trout and razorback sucker, amphibians such as the Tarahumara frog, reptiles such as the Mexican garter snake, birds such as the masked bobwhite and willow flycatcher and mammals such as the water shrew.

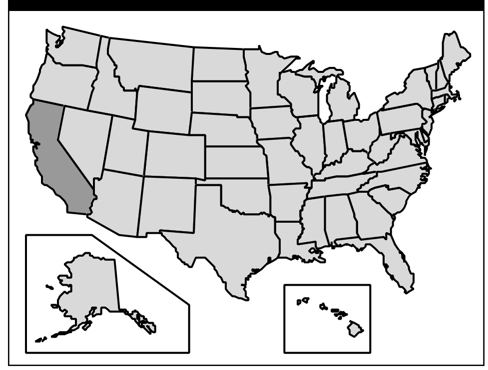
Southern California Coastal Sage Scrub

The remaining coastal sage scrub of southern California, which has decreased by perhaps 90 percent since European settlement, has become some of the most controversial habitat in the country. Situated on real estate worth billions of dollars, this scrubland dominated by California sagebrush, buckwheat and several herbaceous sage *(Salvia)* species is also a hotbed of rare species. The most widely publicized is the coastal California gnatcatcher, federally listed as threatened, but an additional 73 plant and animal species found here are either already federally listed as endangered or threatened, have been proposed for listing or are candidates[305]. This is a tremendous number for such a small geographic area. Some of these imperiled species are the San Diego cactus wren, orange-throated whiptail, Hermes copper butterfly, Pacific pocket mouse, Orange County mariposa lily, San Diego barrel cactus and Santa Ana River woollystar. The state's Natural Community Conservation Planning program, may help to preserve critical scrub habitat. The voluntary program would allow developers to destroy a limited amount of coastal sage scrub if they cooperate in protecting the most important expanses. However, because most of the remaining scrub is on private land that can be worth up to millions of dollars an acre, and because the funding mechanisms for establishing reserves are not in place, it is unclear whether the program will work[306].

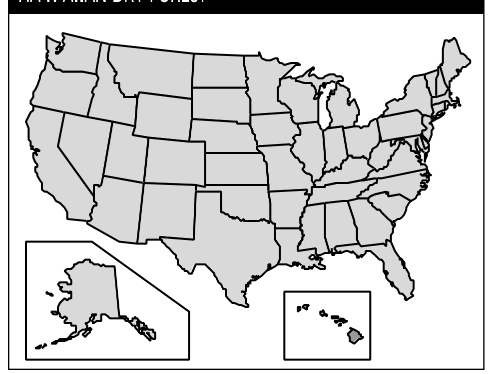
Hawaiian Dry Forest

Although Hawaii is perhaps best known for its rainforests, the state's dry forests are in much greater danger. Dry forests are found predominantly on leeward mountain slopes and receive less than 50 inches of rainfall per year. Their diversity rivals that of rainforests, but dry forests are structurally simpler, with fewer layers of vegetation. Lowland dry

SOUTHERN CALIFORNIA COASTAL SAGE SCRUB



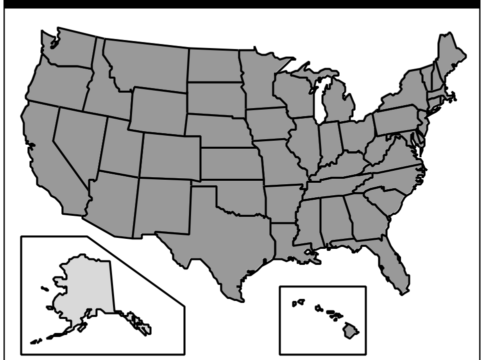
HAWAIIAN DRY FOREST



forests contain many deciduous tree species. Rainfall may be as little as ten inches a year. Grading slowly into shrubland and grassland, these forests are open and savanna-like.

Polynesians began destroying Hawaii's dry forests prior to European contact. Today, an estimated 90 percent of the dry forests and their associated shrublands and grasslands are gone[307]. Alien trees and grasses, along with feral goats, pigs, cats and other animals, have invaded many of these communities. As a result, the remaining dry forests contain some of the rarest trees in Hawaii such as the nearly extinct *Hibiscadelphus* and *Kokia.*

LARGE STREAMS AND RIVERS



Dry forests are also home to many listed and candidate species of vines, shrubs, trees, herbs and birds. The endangered palila, a grey and yellow finchlike bird with a heavy beak, is one such species. It feeds primarily upon the seeds and flowers of the mamane tree — a food source whose range has been reduced by hundreds of square miles because of grazing pressure.

Large Streams and Rivers in The Lower 48 States and Hawaii

People settled along rivers for a number of reasons, primarily water supply, waste removal and transport of goods. When towns were damaged by floods, dams and levees were built. Streams were channelized and water diverted to farm fields. Sewage, chemicals and silt from farmlands and construction sites polluted the water.

Scientific data on the biological condition of specific rivers and other aquatic ecosystems are often hard to come by. Nevertheless, throughout the 48 conterminous states and Hawaii it is difficult to find a large stream or river that has not been dammed, channelized, polluted or otherwise degraded significantly from its natural condition. Between 90 and 98 percent of the nation's rivers are degraded enough to be unworthy of federal designation as wild or scenic. In the lower 48 states there are only 48 high-quality rivers longer than 124 miles that do not have at least one major dam[308] in their headwaters. In the Mississippi Alluvial Plain, virtually every stream has been channelized, leveed or otherwise altered[309].

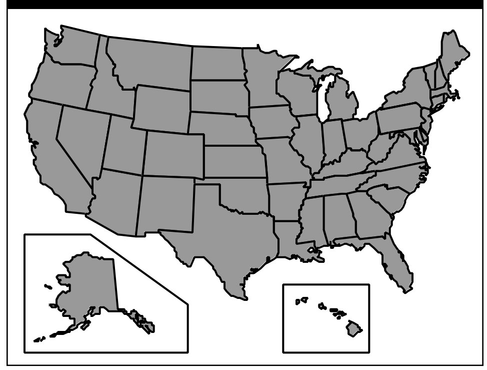
More than 80 percent of the nation's fish communities are considered degraded because of loss or declines in native species or presence of exotic species[310]. Invertebrates are in even worse condition. The Southeast is the center of diversity for freshwater mussels worldwide, yet we have lost one in ten of our freshwater mussel species in the last century and The Nature Conservancy considers half to three quarters of the remaining species to be imperiled or very rare[311]. The Mobile River Basin of Alabama has 40 endemic fish species, 30 endemic mussels and 130 endemic snails. At least 18 mussel species and 32 snail species are already extinct, and 30 additional aquatic species are listed under the Endangered Species Act[312]. These losses are symptomatic of degraded ecosystems. Today, the greatest number of high-quality streams remain in the south Atlantic states (Maryland, Delaware, West Virginia, North Carolina, South Carolina, Georgia and Florida), where streams have the least protection[313].

Cave and Karst Systems

Karst, a soluble rock matrix (such as limestone) honeycombed by caves, springs and sinkholes, underlies between 20 and 25 percent of the United States[314]. Supporting a unique and highly sensitive fauna, karst systems are most abundant in the Appalachian and eastern regions but can be found to some degree in every state. Missouri and Tennessee, for example, are 60 percent karst and home to an estimated 5,000 caves each, but even a state that is only five percent karst, such as California, may have dozens of caves[315]. Because of its volcanic origins, Hawaii has no karst, but underground tubes formed by flowing lava support similar biotic communities. Both karst and lava tube systems contain a wide variety of endemic species, including specially adapted arthropods, snails, flatworms, salamanders and fish. New species are still being discovered, some known only from specimens recovered during well drilling[316].

Nationwide, cave and karst habitat is declining in quality. Most known cave systems have been damaged by various pollutants, including industrial wastes, municipal sewage, hazardous chemical spills and runoff from polluted surface areas. These pollutants run quickly down through the faults in the karst, poisoning the underground habitat. According to cave ecologists, a single surge of contaminated water can wipe out an entire system[317]. Overuse of groundwater also contributes to the decline of cave and karst ecosystems by drawing water levels down and depriving aquatic species of essential habitat[318]. In central Texas, introduced fire ants began colonizing karst areas in the late 1980s, preying on cave crickets, pseudoscorpions and other cave fauna[319]. Eighteen cave-dependent species are listed under the Endangered Species Act, including cave fish, beetles, crayfish, cave shrimp and three species of bats[320]. Bats are especially sensitive to use of caves by recreationists, and many bat colonies have been wiped out by dynamite, shotguns and fire[321]. All federally listed endangered arachnids are in caves in Texas[322], where development and groundwater use have

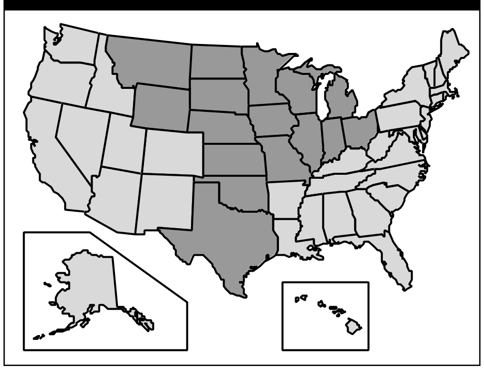
CAVE AND KARST SYSTEMS



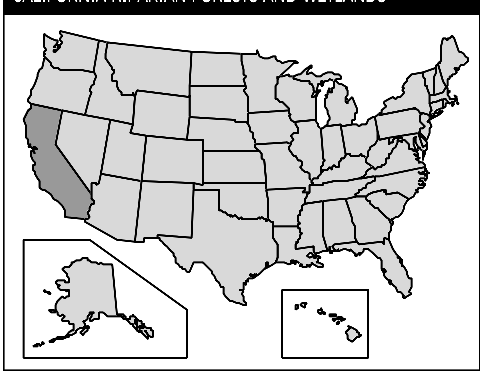
degraded large areas of cave habitat. Dozens of additional species are federal listing candidates or are on state lists[323].

Cave and karst ecosystems operate on extremely low energy budgets because they receive virtually no direct sunlight and therefore lack green plants[324]. A square foot of habitat in a typical midwestern cave receives 2,000 times less energy input than it would if it were on the surface[325]. Once damaged, these ecosystems may be extremely slow to recover because of the low metabolism and population levels of cave organisms. Nonetheless, recovery of damaged cave systems is possible with control of pollution sources. For example, in Horse Cave, Kentucky, installation of a sewage treatment plant has resulted in improved habitat quality and a gradual recovery of cavefish, isopods and other cave species[326]. Unfortunately, the condition of most karst ecosystems is difficult to determine in detail because of the lack of funds for even the most basic research.

TALLGRASS PRAIRIE



CALIFORNIA RIPARIAN FORESTS AND WETLANDS



Tallgrass Prairie

The magnificent tallgrass prairie of the Midwest and Great Plains was a biome unique to North America, a mosaic of many different plant communities covering an immense expanse of the continent. Millions of bison thundered across these prairies, and fires roared over thousands of square miles.

Today the picture is very different. An estimated 99 percent of the tallgrass prairie east of the Missouri River has been destroyed, primarily by agriculture, with losses west of the Missouri River of about 85 percent[327]. Prairie survived only in tiny fragments that were too rocky, sandy, wet, dry or inaccessible to plow and which burned regularly. Many prairie relics survived along the fencerows of old cemeteries and along railroad rights-of-way, areas that were never plowed but were mowed or burned to control invading woody plants. These fragments were too small to sustain bison, elk, wolves or even large birds such as the greater prairie chicken, which is missing from some midwestern states (See Iowa case study, page 35). Although many prairie restoration projects have been undertaken, the work is difficult and most restored sites are less than 200 acres in area.

California Riparian Forests And Wetlands

Agriculture has been the primary culprit in the destruction of riparian forests and wetlands in California, especially in the Central Valley. Livestock grazing and urban development are also important contributors. Estimated losses of riparian forest throughout California are close to 90 percent[328]. Losses in the Central Valley, and especially along the Sacramento River, may be as high as 98 percent. Some particular communities, such as riparian oak forests in the Central Valley, have declined by as much as 99.9 percent. Similarly, estimates of wetland losses in California range from 91 percent statewide to 94 to 96 percent in the Central Valley. Vernal pools, unique wetlands that form briefly with winter rains and are home to many uncommon and endemic plants — including meadowfoam and small-flowered monkeyflower — have declined by as much as 88 percent in the Central Valley and 97 percent in southern California (for example, San Diego County). Approximately 80 to 90 percent of coastal wetlands have disappeared[329].

Florida Scrub

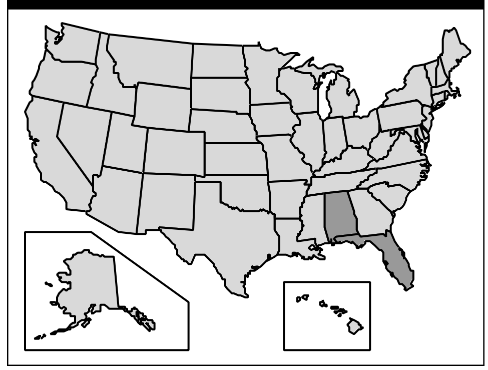
The Florida scrub is a community unique to Florida and a small area of coastal Alabama. It occupies dunes and ridges, both coastal and inland, many of which are ancient shorelines and islands. Scrub vegetation may be sparse, with abundant bare sand and patches of lichens and Florida rosemary; it may be thickets composed of several species of scrub oaks; or it may be dense stands of sand pine. These communities generally form a successional sequence, which is reset every ten to 50 years by intense, stand-replacing fires[330]. Some 65 to 75 percent of the scrub has already been eliminated by citrus farming and housing development, and many sites are in immediate danger[331].

The ancient scrubs of Lake Wales Ridge in south-central Florida are particularly valuable to conservation because they have some of the greatest densities of endemic plants of any continental habitat in the world, as well as several endemic animals, including sand-swimming lizards and the Florida scrub jay. These endemic species and subspecies apparently evolved during interglacial periods when the sea level was much higher than today and present scrub sites were an archipelago of islands. Many of the endemic species are federally listed under the Endangered Species Act.

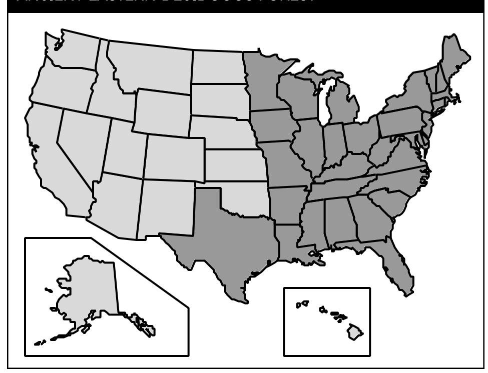
Ancient Eastern Deciduous Forest

The broad category of eastern deciduous forest includes hundreds of plant communities, some more endangered than others. Nonetheless, they have one thing in common — primary (virgin) and old-growth stands have been virtually eliminated. This is not surprising, given that the eastern deciduous forest was the first biome in North America to be intensively settled and exploited. Forests were rapidly cut for agriculture, firewood and construc-

FLORIDA SCRUB



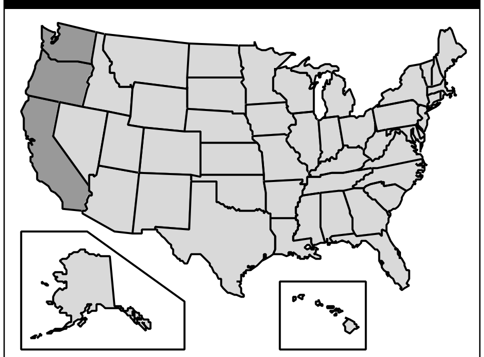
ANCIENT EASTERN DECIDUOUS FOREST



tion and were largely gone by 1900. Remaining forest suffered extinction of key species, such as the American chestnut from an introduced fungal blight and the passenger pigeon from overhunting and fragmentation of the original forest.

In 1920 it was estimated that 96 percent of the virgin forest of the northeastern and central states had already been destroyed[332]. Today most authorities agree that over 99 percent has been lost[333]. The biological consequences of this loss are obscure, but it certainly has contributed to the extirpation of many of the species lost from the eastern states. In regions such as the southern Appalachians, most of the terrestrial species listed as threatened or endangered are associated with deciduous forest, especially older stands.[334]

ANCIENT FOREST OF THE PACIFIC NORTHWEST



Remnant ancient stands are still being discovered and may be more numerous than previously suspected, but virtually all are tiny.[335] Some second-growth forest is regaining its old-growth characteristics a century or more after cutting, but studies have suggested that centuries may be required for the herbaceous species composition of these stands to recover fully[336].

Ancient Forest of the Pacific Northwest

Thanks to the concerted efforts of conservationists and scientists, the old-growth forest of the Pacific Northwest is probably the best-known ancient forest in the world[337]. This is the "westside" forest that occurs from northwestern California through western Washington west of the crest of the Cascade Mountains. Included in this broad region is the Klamath-Siskiyou province of northwestern California and southwestern Oregon, one of the world's centers of temperate biodiversity. An estimated 3,500 plant species, 280 of them endemic, occur within the 8.5 million acres of the Klamath-Siskiyou region[338]. Skirting the Klamath-Siskiyou are the coastal redwoods, the largest living things in the world, more than 300 feet tall with diameters sometimes exceeding ten feet. We do not include in this broad category the forest on the "eastside" of the Cascade Mountains mostly dominated by ponderosa pine and discussed separately, nor do we include the ancient temperate rainforest of southeastern Alaska.

The Douglas-fir, the dominant tree during the first several hundred years of succession in most of the westside forest, rivals the coastal redwood in height and biomass. Douglas-fir is shade-intolerant and usually requires fire or other major disturbance to regenerate. It is slowly replaced during succession by western hemlock, but because Douglas-firs can live longer than 1,000 years, complete replacement takes a long time. Western red cedar, another giant, grows on wetter sites, and Sitka spruce and western hemlock dominate the temperate rainforest within a few miles of the coast. Collectively, this forest is habitat for hundreds or even thousands of species, some yet to be described. Four federally listed species and 22 candidates are associated with old-growth Douglas-fir forest[339]. Among them are the northern spotted owl, marbled murrelet, Siskiyou mountain salamander, Pacific fisher and cold-water corydalis, a plant with pink-tipped white flowers that grows near mountain streams.

Avidly exploited for timber, the old-growth forest has been reduced by some 90 percent[340]. After many court battles over the fate of the remaining forest, President Clinton established a plan to allow logging of some 30 percent, while the rest would be protected as habitat for the northern spotted owl, marbled murrelet, salmon and other species[341]. This plan is in jeopardy because Congress recently legislated increased cutting.

Ancient Red and White Pine Forest

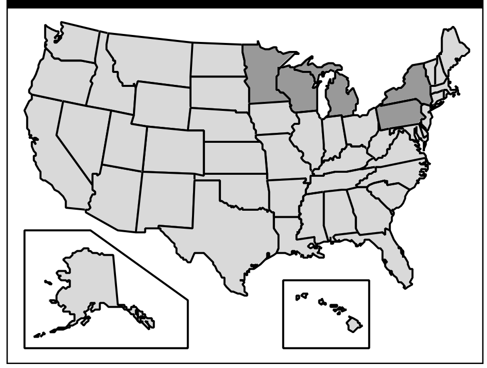
The Great Lakes states, especially northern Michigan and much of northern Wisconsin and Minnesota, once boasted substantial tracts of ancient forest distinguished by red or white pines. The tallest of all eastern trees, the white pine sometimes exceeded 200 feet in height.

In northern Michigan most of these prime timber trees had been cut by the late 19th century. Selective cutting and subsequent slash fires, sometimes covering the area of several counties, converted the red and white pine forests to scrubby thickets of oak sprouts, aspen suckers and shrubs. Today, only about 2,000 of Michigan's original 4 million acres of ancient red and white pine forest — five hundredths of one percent — remain[342]. Minnesota has lost nearly 86 percent of its red and white pine forests, and much of what remains is red pine plantations[343]. The biological consequences of this vast ecological change must have been devasting, but were not documented by scientists.

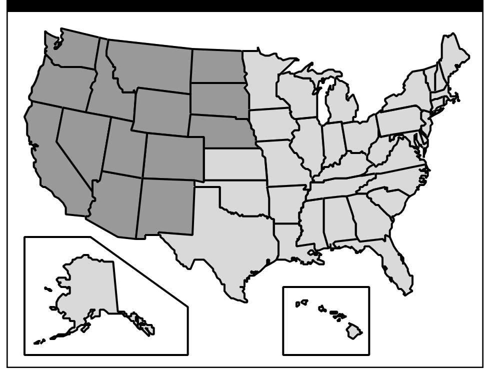
Ancient Ponderosa Pine Forest

Ponderosa pine occurs mostly in the Intermountain West from southwestern Canada to Mexico, although the species extends as far east as the Dakotas and

ANCIENT RED AND WHITE PINE FOREST

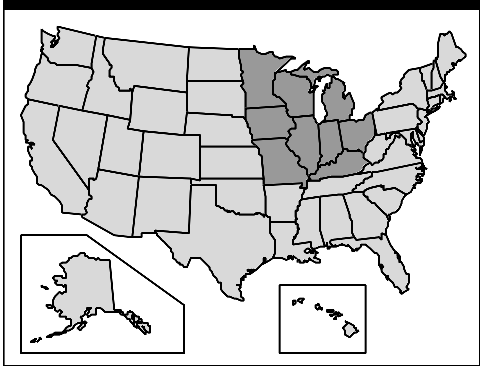


ANCIENT PONDEROSA PINE FOREST



Nebraska and as far west as Oregon's Willamette Valley and the Transverse Ranges of California. Although community composition changes markedly across this vast area, old ponderosa pine forests are characteristically open and park-like, maintained by frequent low-intensity ground fires. These stands are often called savannas, because they are grassy slopes or flats with interspersed old-growth or "yellow-belly" pines as well as younger pines. Thus ponderosa pine stands may be considered the ecological equivalents of the longleaf pine forests and savannas of the Southeast.

MIDWESTERN WETLANDS



Ponderosa pine forests have been heavily affected by logging, both clearcutting and selective cutting; the latter is often called "high-grading" because the superior trees are removed from the stand. This process has probably resulted in genetic deterioration of many stands. An even more severe threat has been fire suppression, which has resulted in crowded stands dominated by small trees and highly susceptible to drought, disease and insect attack[344]. Fire suppression also has allowed invasion of ponderosa pine stands by Douglas fir, true firs and other woody plants less tolerant of fire and more tolerant of shade.

Losses of old-growth ponderosa pine have not been reliably estimated in many regions. However, a study of three national forests in eastern Oregon found 92 to 98 percent losses of old-growth ponderosa pine[345]. Some 60 to 70 percent of remaining ponderosa pine in Idaho is considered degraded by fire suppression, and the more accessible areas have been high-graded. The status of species associated with these forests is not well documented, but white-headed woodpeckers and flammulated owls appear to be declining.

Midwestern Wetlands

Although wetlands have declined substantially throughout the country, those of the Midwest have been notably hard hit, particularly in the southern regions. Summary statistics for the 1780s to the 1980s compiled by the U.S. Fish and Wildlife Service show total wetland losses of 90 percent in Ohio, 89 percent in Iowa, 87 percent in Indiana and Missouri, 85 percent in Illinois, 50 percent in Michigan and Minnesota, 49 percent in North Dakota, 48 percent in Kansas, 46 percent in Wisconsin and 35 percent in Nebraska and South Dakota[346]. Some other researchers concluded that losses are even higher, for example 99 percent in Iowa and Illinois[347].

There are relatively poor data available on individual wetland types, but some figures include a 65 to 77 percent loss of fens in Iowa, an 80 percent loss of southern tamarack swamp in Michigan, a 60 to 70 percent loss of coastal marsh in Michigan, a greater than 99 percent loss of sedge meadows in Wisconsin, a 90 percent loss of eastern Nebraska saline wetlands and a 60 to 65 percent loss of prairie potholes in the upper Great Plains[348]. The major cause of midwestern wetland loss has been draining for agriculture. However, woody plant invasion (often related to fire suppression), livestock grazing, mining and urban development have all played a role in the decline. Rare wildlife associated with midwestern wetlands includes the northern copperbelly watersnake, fox snake and Blanding's turtle.

Southern Forested Wetlands

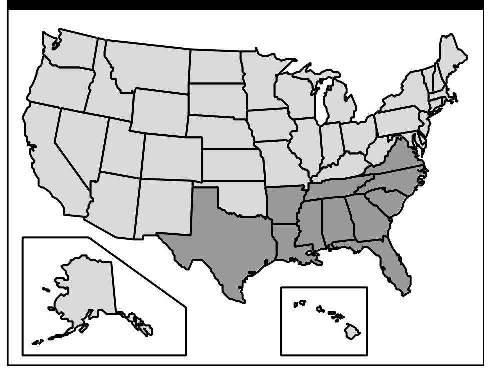
This category includes the bottomland hardwoods forest associated with the rivers of the South and several other imperiled communities, such as the Atlantic white cedar swamps.

The bottomland hardwoods forest, with its gigantic cypress and gum trees, Spanish moss, lazy tea-colored waters and alligators, is among the most enchanting ecosystems on Earth. It has been extensively logged and the rivers that nourish it have been channelized, leveed and dammed. As a result, bottomland hardwoods forest has declined approximately 80 percent and the remaining forest stands are greatly diminished in quality as the result of selective logging that has removed large cypresses and other valuable trees[349].

Atlantic white cedar swamps originally stretched from southern New England along the coastal plain of the Atlantic and Gulf of Mexico to Mississippi, with the greatest concentration in the Great Dismal Swamp of Virginia. This community has declined by some 98 to 99 percent in the Great Dismal Swamp and possibly across its entire range[350].

The ivory-billed woodpecker was one of the inhabitants of southern forested wetlands. It is now extinct on the mainland and on the verge of extinction in Cuba. Many hard-pressed species, including the Louisiana black bear, depend on what remains of this magnificent ecosystem.

SOUTHERN FORESTED WETLANDS



APPENDIX C

Calculation of Overall Risk Index

The Overall Risk Index (ORI) is illustrated on Map 1 and Table 5 (pages 20 and 118). Potential ORI scores theoretically could range from 0 to 24, although in practice the highest calculated ORI score was 23 for Florida. To calculate the ORI value for each state, we combined the scores from three separate indices, giving each score equal weight. These indices, discussed below, represent (1) the number of 21 most-endangered ecosystems that occur in the state, (2) the percentage of the state's species that are imperiled and (3) the amount of existing development and threat of continuing development. Florida, for example, had an Ecosystems Risk Index score of 8, a Species Risk score value of 7 and a Development Risk Index score of 8 for an ORI total of 23. Table 6 (page 119) lists each state's ORI scores and the three indices scores that comprise it. Figure 3 (page 132) illustrates the relationship between the different indices.

Ecosystem Risk Index (ERI)

The Ecosystem Risk Index (Map 2) is based on the number of most-endangered ecosystems in each state ("most-endangered" is defined in Section 1). On our scale, a state with one endangered ecosystem received an ERI score of zero. A state with two most-endangered ecosystems received a score of 1, and so on up to a maximum score of 8 for Florida with nine most-endangered ecosystems. We counted a state as having a most-endangered ecosystem if the state contained at least one good example of the ecosystem. All states contain at least one most-endangered ecosystem, namely "cave and karst systems" and all but Alaska have "rivers and streams of the lower 48 states and Hawaii" and "coastal communities of the lower 48 states and Hawaii." Table 9 (page 125) lists the number of most-endangered ecosystems in each state and all ERI scores.

In interpreting the real-world implications of our Ecosystem Risk Index, one should bear in mind the difference between the most-endangered ecosystems as we have defined them for this report and the ecosystems defined in the recent National Biological Service (NBS) report on endangered ecosystems. Briefly, our most-endangered ecosystems are large, often extending across several or more states, and most of them lump together many of the community-scale ecosystems from the NBS report. Therefore, although a given state might contain only a few of our most-endangered ecosystems, it could still have many of the smaller, seriously endangered community-level ecosystems listed in the NBS report or identified as rare by the Network of Natural Heritage Programs and Conservation Data Centers and The Nature Conservancy (the Heritage\Conservancy). Many of these endangered community-level ecosystems and estimates of their percentage decline are listed in Table 1 (page 108).

Species Risk Index (SRI)

The Species Risk Index (Map 3) is a measure of the percentage of a state's imperiled species. States with a high SRI have larger percentages of imperiled species than those with lower SRIs. We based our analysis on data provided by the Heritage\Conservancy. For several groups of organisms, we calculated the percentage of species in a state that are G1 ("highly imperiled") or G2 ("imperiled") according to the Heritage\Conservancy classification scheme. A species rated G1 typically has very few remaining individuals and occurs at five or fewer locations. A species rated G2 occurs at six to 20 locations and has a relatively small total population.

Good data on distribution and endangerment are only available for a few taxonomic groups. Our SRI is based on data for four such groups: vertebrates, plants and aquatic invertebrates. (We combined mussels and crayfish into a single category which we called "aquatic invertebrates.") Although the vertebrate and plant groups also contain some freshwater species (for example, fish and water plants), they are heavily weighted toward terrestrial species. Therefore, we included the aquatic invertebrate group to give more emphasis to the extensive destruction of freshwater ecosystems.

We combined data on mussels and crayfish into a single score for aquatic invertebrates, because the number of species of either in a typical state is relatively low compared to the number of plants or vertebrates. We did this by calculating the percentage of G1 or G2 mussels in a state. To this was added the percentage of crayfish that are either G1 and G2 and the sum was divided by two. This gave us an average for aquatic invertebrates that weighted mussels and crayfish equally.

In some cases, a state had very few species of crayfish or mussels. If the total number of either crayfish or mussel species in the state was five or fewer, we excluded data for that group from the score for aquatic invertebrates. In the case of Montana, there are 77 mussel species but only two crayfish. Therefore, crayfish were not included when calculating the Montana score for aquatic invertebrates. If neither crayfish nor mussels had more than five species occurring in the state, data for both groups were discarded and the SRI was calculated using only data for plants and vertebrates.

To calculate the SRI score, we converted the percentages of G1 and G2 species for each taxonomic group to a score from 1 to 8. The method is best explained by example. For plants, scaling intervals were one percent wide. Thus we gave a state an index value of 1 if fewer than one percent of its plant species fell into the G1 or G2 categories, a 2 if it had between one and two percent G1 and G2 species, up to a maximum value of 8 if it had more than seven percent G1 and G2 species. South Dakota, with 0.3 percent of its plants imperiled scored a 1, while Hawaii with nearly 30 percent imperiled plants scored an 8.

Vertebrates were scored identically. For aquatic invertebrates we used a scaling interval of three meaning that a state received an index value of 1 if the combined percentage of G1 and G2 species for mussels and crayfish fell between one and three percent, a 2 if it fell between three and six percent and so on.

Then we added the three scores for plants, vertebrates and aquatic invertebrates. The sums, which theoretically could range from 3 to 24, were then rescaled from 1 to 8 to yield the SRI score.

In the case that aquatic invertebrates were not included because the state contained an insufficient number of species, only the scores for vertebrates and plants were added together, yielding sums from 2 to 16. These sums were also scaled from one to eight. In either case, a state received an SRI score ranging from 1 to 8 that could later be used to calculate the Overall Risk Index for the state.

One caveat in interpreting SRI values is that these values are based on the number of imperiled species known to exist now in the state. If a state has already lost many species because of large-scale habitat destruction, these losses would not be reflected in the Heritage\Conservancy rarity data. Therefore, it is theoretically possible for a state to have had many recent extinctions but still have a low SRI value. This may be the case for some eastern and midwestern states where development has been extensive and many native vertebrates no longer occur (See Iowa case study, p[age 35). Thus, SRI values indicate current vulnerability of existing species and may shortchange the extent of past environmental destruction.

Development Risk Index (DRI)

The third index used to calculate ORI was the Development Risk Index (Map 4), which in turn is composed of two subindices: Development Status Subindex and Development Trend Subindex.

• **Development Status Subindex.** The Development Status Subindex (Map 5) represents the degree to which a state has already been developed. It is derived from four equally weighted measures: (a) population density, (b) percentage of the state developed as of 1992, which is the most recent year for which data are available, (c) percentage of the state in farm land and (d) rural road density. Raw data for these statistics are in Table 10 (page 126).

• Development Trend Subindex. The Development Trend Subindex (Map 6) is based on four equally weighted measures of the rate of development from 1982 to 1992. Because we considered development trend more important in indicating future threat to ecosystems than the degree of development to date, we gave the Development Trend Subindex twice the weight of the Development Status Subindex in calculating the overall Development Threat Index (Figure 3, page 132).

The four measures used to calculate the Development Trend Subindex are (a) the number of people added per square mile during the decade, (b) the percentage change in population density, (c) the percentage of the state that became developed during the decade and (d) the percentage change in the total amount of developed land during the decade. Consider an example to distinguish between these last two. In Florida, three percent of the land in the state was developed between 1982 and 1992. This was a 35 percent increase over the amount of land that had been developed prior to 1982.

The raw data for the four measures incorporated in the Development Trend Subindex are presented in Table 11 (page 128). Note that a state could have added a large number of people per square mile during the decade, yet have a small percentage change in density if the initial population in 1982 was already high or vice-versa. For example, New Jersey added 50 people per square mile, more than any other state except Florida and Maryland, yet its percentage change in population density was only five percent (compared to 29 percent for Florida) because its population density exceeds 1,000 people per square mile. One interesting result of our analysis is that some states which already have high population densities are still adding large numbers of people to already overburdened environments.

Methodological Considerations

The results of any attempt to rank states using indices will be influenced by decisions about which raw data to use, how to divide the data into intervals, which sub-indices to use and how to weight the subindices. For example, of the three indices incorporated by the ORI, two — the Ecosystem Risk Index and the Species Risk Index — represent different measures of ecological health. Although we chose to assign only one third of the total ORI to development risk, other researchers might have chosen to give development risk greater weight. Doing so would have lifted some highly developed states such as New Jersey and Delaware in the ORI rankings. One can assess the relative importance of these indices in the ranking of any individual state by reviewing the state's DRI, SRI and ERI values in Table 6 (page 119).

ORI rankings were also sensitive to decisions about how to deal with outlying data points and interval width and number. For example, Hawaii's percentage of imperiled plants, nearly 30 percent, falls far outside the normal range — more than twice as great as the next highest state. If we made the scoring intervals wide, say 4 percentage points, then Hawaii would receive a score of 8, California — the next highest state — would receive a score of 4, six states would receive scores of 3 and all the others scores of 1. By giving most states scores of 1, this method would obscure substantial differences among the lower-scoring states. We opted to use an interval of 1 percentage point, which distinguished well between states at the low end of the scale but made no distinction between Hawaii and California — both scored 8 points on the Species Risk Index. Because we thought that Hawaii's case was so special, given its high percentage of imperiled species and high level of endemism, we compensated in this one case by giving Hawaii four extra points on the SRI index for a total of 12. In analyzing our data we also chose to give the intervals constant width rather than base them on percentiles and to use eight intervals for each index.

Although we are confident that our method of interval calculation makes good sense in terms of the questions we asked, we also analyzed the data using alternative widths and numbers of intervals in order to see how much the rankings would change. Our assumption was that if rankings were to remain similar using different interval methods, we would have more confidence in our results. We found that although changes in rank occurred, overall these were minor and high-ranked states stayed near the top regardless of method. For example, we also calculated ORI using a method to broaden the intervals to emphasize outliers. In the case of population density, this calculation method gave most states smaller scores compared to New Jersey and other states with high population densities. Although using this method changed half the states' ORI scores, no state changed by more than one or in a few cases, two points and Florida and California remained at the top of the list.

APPENDIX D

Capsule Summaries Of State Risk Statistics

The following definitions pertain to statistics in the capsule summaries:

- Listed Species include all of those that are threatened and endangered as listed by the U.S. Fish and Wildlife Service.
- Candidate Species are those under study by the U.S. Fish and Wildlife Service* for possible listing but not yet listed.
- Imperiled Vertebrates and Imperiled Plants are species designated by The Nature Conservancy as G1 or G2, meaning that they are especially vulnerable or very vulnerable to extinction throughout their ranges.
- "Developed" means urban and suburban areas of ten acres or more and does not include cropland, pasture land, rangeland or forests**.

Alabama

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 89
- Number of Candidate Species: 276
- Number of Imperiled Vertebrates: 45
- Number of Imperiled Plants: 110
- Population density, 1992: 80.03 people per square mile
- Percent change in population density, 1982-1992: 4.97
- Percent of state developed as of 1992: 6.2
- Percent increase in developed land, 1982-1992 -18.8

FACTS

- Loss of all but a few small remnants of Black Belt prairie in Alabama and Mississippi to agriculture
- 50% loss of wetlands in Alabama between 1780s and 1980s

Alaska

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 8
- Number of Candidate Species: 35
- Number of Imperiled Vertebrates: 11
- Number of Imperiled Plants: 41
- Population density, 1992: 1.03 people per square mile
- Percent change in population density, 1982-1992: 32.43
- Percent of state developed as of 1992: no data

*Listed and candidate species data are from U.S. Fish and Wildlife Service. 1995.
**Development and population data are from the *U.S. Bureau of the Census*. 1994.

- Percent increase in developed land, 1982-1992: no data

■ FACTS

- 11% of original coastal temperate rainforests logged

Arizona

- Overall Risk to Ecosystems: High
- Number of Listed Species: 45
- Number of Candidate Species: 228
- Number of Imperiled Vertebrates: 21
- Number of Imperiled Plants: 205
- Population density, 1992: 33.61 people per square mile
- Percent change in population density, 1982-1992: 32.55
- Percent of state developed as of 1992: 1.9
- Percent increase in developed land, 1982-1992: 35.1

■ FACTS

- 90% loss of presettlement riparian ecosystems in Arizona and New Mexico
- 36% loss of wetlands in Arizona between 1780s and 1980s
- 70% loss of cienegas (wet marsh) sites in Arizona since settlement

Arkansas

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 25
- Number of Candidate Species: 98
- Number of Imperiled Vertebrates: 20
- Number of Imperiled Plants: 30
- Population density, 1992: 45.01 people per square mile
- Percent change in population density, 1982-1992: 3.77
- Percent of state developed as of 1992: 3.9
- Percent increase in developed land, 1982-1992: 7.9

■ FACTS

- 99.999 % loss (from 500,00 to 500 acres) of tall-grass prairie
- in Grand Prairie area of Mississippi Alluvial Plain in Arkansas
- 72 % loss of wetlands in Arkansas between 1780s and 1980s

California

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 160
- Number of Candidate Species: 1,103
- Number of Imperiled Vertebrates: 54
- Number of Imperiled Plants: 784
- Population density, 1992: 194.67 people per square mile
- Percent change in population density, 1982-1992: 25.09
- Percent of state developed as of 1992: 4.9
- Percent increase in developed land, 1982-1992: 19.1

■ FACTS

- 99% loss of native grassland (from 22 million to 220,000 acres)
- 94.2% loss of native grassland in San Diego County
- 26% of native annual and perennial grasslands destroyed between 1945 and 1980
- 8,653% increase in non-native annual grassland
- 99.9% loss of needlegrass steppe
- 90% loss of north coastal bunchgrass
- 68.2% loss of alpine meadows
- 100% loss of coastal strand in San Diego County

- 70-90% of presettlement coastal sage scrub destroyed
- 66% or less of southern California coastal sage scrub lost since settlement
- 91.6% loss of maritime sage scrub and 87.7 % loss of coastal mixed chaparral in San Diego County
- >99% loss (virtual extirpation) of alkali sink scrub in southern California
- 25% of non-federal forests and rangelands are experiencing excessive surface soil erosion
- 85% loss of coastal redwood forests
- 32% loss of redwood forests and mixed conifer forests
- 72% loss of woodland and chaparral on Santa Catalina Island
- 89% loss of riparian woodland statewide
- 88.9% loss of Central Valley riparian forests
- 99% of Central Valley riparian forests destroyed within 100 years after settlement
- 90-98% decline of Sacramento River riparian and bottomland forests
- 99.9% loss of Central Valley riparian oak forest
- 60.8% loss of riparian woodland in San Diego County
- 91% loss of wetlands (all types) between 1780s and 1980s
- 94% loss of inland wetlands
- 69% loss of tule *(Scirpus)* marsh
- 94-96% loss of Central Valley interior wetlands
- 31.5% loss of wetlands and deepwater habitats in Central Valley between 1939 and mid-1980s
- 66-88% loss of Central Valley vernal pools
- 96.5% loss of vernal pools in San Diego County
- 90.1% loss of freshwater marsh in San Diego County
- 80% of coastal wetlands converted to urban or agricultural uses
- 62% loss of salt marshes
- 87.8% loss of coastal salt marsh in San Diego County
- 90% loss of seasonal wetlands around San Francisco Bay
- 80% loss of tidal marshes in San Francisco Bay

Colorado

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 29
- Number of Candidate Species: 102
- Number of Imperiled Vertebrates: 7
- Number of Imperiled Plants: 97
- Population density, 1992: 33.29 people per square mile
- Percent change in population density, 1982-1992: 12.87
- Percent of state developed as of 1992: 2.5
- Percent increase in developed land, 1982-1992: 22.4

■ FACTS

- 50% loss of wetlands in Colorado between 1780s and 1980s

Connecticut

- Overall Risk to Ecosystems: High
- Number of Listed Species: 17
- Number of Candidate Species: 28
- Number of Imperiled Vertebrates: 3
- Number of Imperiled Plants: 17
- Population density, 1992: 653.35 people per square mile
- Percent change in population density, 1982-1992: 4.89
- Percent of state developed as of 1992: 25.4
- Percent increase in developed land, 1982-1992: 11.5

■ FACTS

- 74% loss of wetlands in Connecticut between 1780s and 1980s
- 97% of Connecticut coastline developed
- >50% of Connecticut tidal wetlands lost since 191

Delaware

- Overall Risk to Ecosystems: High
- Number of Listed Species: 17
- Number of Candidate Species: 24
- Number of Imperiled Vertebrates: 4
- Number of Imperiled Plants: 24
- Population density, 1992: 337.85 people per square mile
- Percent change in population density, 1982-1992: 15.17
- Percent of state developed as of 1992: 15.7
- Percent increase in developed land, 1982-1992: 20.6

■ FACTS

- 54% loss of wetlands in Delaware between 1780s and 1980s

Florida

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 97
- Number of Candidate Species: 286
- Number of Imperiled Vertebrates: 32
- Number of Imperiled Plants: 214
- Population density, 1992: 229.83 people per square mile
- Percent change in population density, 1982-1992: 28.78
- Percent of state developed as of 1992: 12.4
- Percent increase in developed land, 1982-1992: 34.6

■ FACTS

- Loss of virtually all of dry prairies of Florida to cattle pasture and agriculture
- 27% loss of total forest acreage from 1940 to 1980
- 88% decline of longleaf pine forests from 1936 to 1987
- 64% loss of Florida sand pine scrub on Lake Wales, Lake Henry and Winter Haven Ridges since settlement
- 60.5% of flatwoods/swale habitats on southern Lake Wales Ridge lost to development or degraded
- 88% loss of slash pine forests in southwest Florida from 1900 to 1989
- >98% loss of pine rockland habitat
- 60-80% loss of tropical hardwood hammock on central Florida keys
- 74.4% of xeric habitats (scrub, scrubby flatwoods and sandhills) on southern Lake Wales Ridge lost to development or degraded
- 46% loss of wetlands between 1780s and 1980s
- >50% loss of presettlement wetlands (all types)
- 92% loss of mangrove swamp and salt marsh along Indian River Lagoon between 1955 and 1974 due to impoundment for mosquito control
- 56% decline of marsh (herbaceous wetland) habitat from 1936 to 1987
- 51% loss of freshwater marshes in southwest Florida from 1900 to 1989
- 25% of bayhead wetlands on southern Lake Wales Ridge lost to development or degraded
- 33% loss of seagrass beds that existed before WWII
- 75% loss of seagrass meadows in Tampa Bay

Georgia

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 55
- Number of Candidate Species: 193

- Number of Imperiled Vertebrates: 35
- Number of Imperiled Plants: 141
- Population density, 1992: 114.97 people per square mile
- Percent change in population density, 1982-1992: 19.85
- Percent of state developed as of 1992: 8.2
- Percent increase in developed land, 1982-1992: 32.8

■ FACTS

- >80% of original forests in northern Georgia Piedmont cleared by 1930
- 23% loss of wetlands in Georgia between 1780s and 1980s

Hawaii

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 224
- Number of Candidate Species: 428
- Number of Imperiled Vertebrates: 38
- Number of Imperiled Plants: 406
- Population density, 1992: 178.66 people per square mile
- Percent change in population density, 1982-1992: 15.95
- Percent of state developed as of 1992: 4.1
- Percent increase in developed land, 1982-1992: 15.6

■ FACTS

- 80% of original habitat below 1,500 feet severely altered by the year 1800
- 67% of original forest cover lost, including 50% of rain forests
- 90% loss of dry forests, shrubland and grassland on all main islands combined
- 61% loss of mesic forest and shrubland on all main islands combined
- 42% loss of wet forest, shrubland and bog on all main islands combined
- 52% (74 of 141) natural community types are considered imperiled or critically imperiled globally
- 12% loss of wetlands in Hawaii between 1780s and 1980s

Idaho

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 18
- Number of Candidate Species: 101
- Number of Imperiled Vertebrates: 10
- Number of Imperiled Plants: 55
- Population density, 1992: 12.76 people per square mile
- Percent change in population density, 1982-1992: 9.11
- Percent of state developed as of 1992: 1.1
- Percent increase in developed land, 1982-1992: 19.1

■ FACTS

- 60-70% of old-growth ponderosa pine forests in Idaho degraded due to fire suppression; also, more accessible areas have been high-graded (logged of superior trees)
- 70% loss of maritime-like forests in Clearwater Basin of Idaho, much of remainder highly fragmented
- 56% loss of wetlands in Idaho between 1780s and 1980s; probably 80-90% of lower elevation wetlands have been lost and most of the rest degraded
- >99% of basin big sagebrush *(Artemisia tridentata)* in Snake River Plain of Idaho converted to agriculture
- 5 to 6 million acres of sagebrush-grass steppe in western Snake River Basin converted to exotic annual vegetation, primarily cheatgrass *(Bromus tectorum)* and medusahead *(Taeniatherum aspe-*

rum), ultimately due to overgrazing

- 50% of current western juniper in Idaho is invasive, having replaced sagebrush-grass communities because of fire suppression
- Virtually all riverine cottonwood forests on big rivers of southern Idaho lack recruitment of younger age classes, mostly because of dams eliminating spring flooding that exposed mineral soil needed for germination
- 99.9% of Palouse prairie throughout its range in Washington, Oregon and Idaho lost to agriculture

Illinois

- Overall Risk to Ecosystems: High
- Number of Listed Species: 24
- Number of Candidate Species: 83
- Number of Imperiled Vertebrates: 12
- Number of Imperiled Plants: 17
- Population density, 1992: 206.1 people per square mile
- Percent change in population density, 1982-1992: 1.28
- Percent of state developed as of 1992: 8.6
- Percent increase in developed land, 1982-1992: 8.4

■ FACTS

- 99% to >99.9% loss of original tallgrass prairie in Illinois
- 89% loss of wetlands in Illinois
- 85% loss of wetlands in Illinois between 1780s and 1980s

Indiana

- Overall Risk to Ecosystems: High
- Number of Listed Species: 20
- Number of Candidate Species: 74
- Number of Imperiled Vertebrates: 11
- Number of Imperiled Plants: 15
- Population density, 1992: 156.36 people per square mile
- Percent change in population density, 1982-1992: 3.21
- Percent of state developed as of 1992: 9.0
- Percent increase in developed land, 1982-1992: 12.8

■ FACTS

- >99% loss of original tallgrass prairie in Indiana
- Virtually all of the black silt-loam and gravel hill tallgrass prairies of Indiana destroyed
- 87% loss of wetlands in Indiana between 1780s and 1980s

Iowa

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 14
- Number of Candidate Species: 50
- Number of Imperiled Vertebrates: 4
- Number of Imperiled Plants: 9
- Population density, 1992: 49.81 people per square mile
- Percent change in population density, 1982-1992: -3.58
- Percent of state developed as of 1992: 4.9
- Percent increase in developed land, 1982-1992: 2.9

■ FACTS

- >99.9% loss of tallgrass prairie in Iowa, with remnants (ca. 30,000 acres) mostly on dry and dry-mesic sites too rocky, sandy, dry or inaccessible to plow
- 35% loss of forest since settlement in Iowa; however, most of this was probably savanna which is virtually extinct

- 98.9% loss of presettlement wetlands (from 2.3 million to 26,470 acres)
- 89% loss of wetlands in Iowa between 1780s and 1980s
- 40% of potential fen sites (and 65-77% of actual fens) in Iowa destroyed by cultivation or drainage; most of the remaining fens altered or threatened by grazing, cropland edge effects, woody plant invasion, drainage, excavation or mining

Kansas

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 14
- Number of Candidate Species: 55
- Number of Imperiled Vertebrates: 9
- Number of Imperiled Plants: 13
- Population density, 1992: 30.57 people per square mile
- Percent change in population density, 1982-1992: 4.49
- Percent of state developed as of 1992: 3.8
- Percent increase in developed land, 1982-1992: 6.5

■ FACTS

- 82% loss of tallgrass prairie in Kansas
- 48% loss of wetlands in Kansas between 1780s and 1980s

Kentucky

- Overall Risk to Ecosystems: High
- Number of Listed Species: 38
- Number of Candidate Species: 114
- Number of Imperiled Vertebrates: 19
- Number of Imperiled Plants: 31
- Population density, 1992: 92.9 people per square mile
- Percent change in population density, 1982-1992: 1.62
- Percent of state developed as of 1992: 6.4
- Percent increase in developed land, 1982-1992: 28.6

■ FACTS

- 100% loss of intact bluegrass savanna woodland in Kentucky
- >99.99% loss of native prairie in Kentucky (from 2.58 million to <200 acres)
- >99.98% loss of virgin forest in Kentucky, with remaining stands disturbed by factors such as grazing or chestnut blight; current forest acreage is 54% of original
- 81% loss of wetlands in Kentucky between 1780s and 1980s
- 79% loss of wetlands in Kentucky (59% drained for cropland, 20% converted to pasture)

Louisiana

- Overall Risk to Ecosystems: High
- Number of Listed Species: 27
- Number of Candidate Species: 68
- Number of Imperiled Vertebrates: 15
- Number of Imperiled Plants: 35
- Population density, 1992: 89.61 people per square mile
- Percent change in population density, 1982-1992: -2.35
- Percent of state developed as of 1992: 5.8
- Percent increase in developed land, 1982-1992: 18.1

■ FACTS

- >99% loss of wet and mesic coastal prairies
- 95-99% loss of Mississippi terrace prairie
- 90-95% loss of calcareous prairie (all types) and

Fleming glades
- 75-90% loss of saline prairie
- 25-50% loss of coastal dune grassland, Catahoula sandstone glades, and coastal dune shrub thicket
- 95-99% loss of wet longleaf pine savannas and eastern upland longleaf pine forest
- 75-90% loss of western upland longleaf pine forest
- 85% loss of natural longleaf pine forests in Texas and Louisiana since 1935
- 95-99% loss of live oak forest, prairie terrace oak loess forest, coastal live oak-hackberry forest, and mature natural forests of all types combined in Louisiana
- 90-95% loss of shortleaf pine/oak-hickory forest, mixed hardwood-loblolly pine forest, eastern xeric sandhill woodland, and stream terrace sandy woodland/savanna in Louisiana
- 75-90% loss of live oak-pine-magnolia forest, mesic spruce pine-hardwood flatwoods, western xeric sandhill woodlands in Louisiana
- 50-75% loss of southern mesophytic forest, calcareous forest and hardwood slope forest in Louisiana
- 50% loss of cedar woodlands
- 85% of forested wetlands of the Tensas Basin, Louisiana, cleared since 1937
- 75-90% loss of flatwood ponds, slash pine-pond cypress/hardwood forest, wet mixed hardwood-loblolly pine flatwoods, and wet spruce pine-hardwood flatwoods
- 50-75% loss of freshwater marsh, interior saline soil marsh, scrub/shrub swamp, bald cypress/cypress tupelo swamp, bottomland hardwood forest, bayhead swamp, and small stream forest
- 25-50% loss of hillside seepage bog, interior salt flat, gum swamp, seepage slope shrub thicket, and upland depressional swamp
- 46% loss of wetlands in Louisiana between 1780s and 1980s
- 25-50% loss of most estuarine communities (salt marsh, brackish marsh, intermediate marsh, intertidal salt flat) in Louisiana
- <25% loss of vegetated pioneer emerging delta

Maine

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 12
- Number of Candidate Species: 32
- Number of Imperiled Vertebrates: 6
- Number of Imperiled Plants: 20
- Population density, 1992: 37.16 people per square mile
- Percent change in population density, 1982-1992: 8.8
- Percent of state developed as of 1992: 3.3
- Percent increase in developed land, 1982-1992: 16.4

■ FACTS

- 20% loss of wetlands in Maine between 1780s and 1980s

Maryland

- Overall Risk to Ecosystems: High
- Number of Listed Species: 24
- Number of Candidate Species: 62
- Number of Imperiled Vertebrates: 9
- Percent of Imperiled Plants: 31
- Population density, 1992: 470.03 people per square mile
- Percent change in population density, 1982-1992: 15.1
- Percent of state developed as of 1992: 16.4
- Percent increase in developed land, 1982-1992: 15.8

■ FACTS

- >90% loss of low-elevation mesic limestone forest in Maryland

- 95% loss of natural barrier island beaches in Maryland
- 50% loss of barrier island dunes
- 73% loss of wetlands between 1780s and 1980s
- >50% loss of Delmarva bays (coastal plain seasonal ponds) in Maryland

Massachusetts

- Overall Risk to Ecosystems: High
- Number of Listed Species: 22
- Number of Candidate Species: 39
- Number of Imperiled Vertebrates: 7
- Number of Imperiled Plants: 25
- Population density, 1992: 723.41 people per square mile
- Percent change in population density, 1982-1992: 4.32
- Percent of state developed as of 1992: 24.7
- Percent increase in developed land, 1982-1992: 21.7

■ FACTS

- 69% loss of pine barrens in Massachusetts
- 48% loss of pine barrens across range (New Jersey, New York, Rhode Island, Connecticut, Pennsylvania, New Hampshire, Massachusetts, Maine)
- 28% loss of wetlands between 1780s and 1980s
- 42% loss of wetlands by 1988
- 28.5% of lakes and ponds threatened or impaired on basis of eutrophic status in 1988
- 61.5% of monitored estuaries and 26% of monitored rivers affected by toxic chemicals in 1988

Michigan

- Overall Risk to Ecosystems: High
- Number of Listed Species: 18
- Number of Candidate Species: 56
- Number of Imperiled Vertebrates: 8
- Number of Imperiled Plants: 19
- Population density, 1992: 161.19 people per square mile
- Percent change in population density, 1982-1992: 3.5
- Percent of state developed as of 1992: 9.8
- Percent increase in developed land, 1982-1992: 14.3

■ FACTS

- 99.93% loss of original blacksoil prairie in Michigan
- 99.3% loss of original dry sand prairie in Michigan
- 99.5% loss of lakeplain wet prairie in Michigan; only 500 acres persist
- >99% loss of original oak barrens (dry savanna) in Michigan, but about 2% remains in good to restorable condition; no intact examples of oak openings (mesic and dry-mesic savanna) known
- 99.95% loss of high quality, mature to old-growth white pine-red pine forest in Michigan
- 99.92% loss of mature to old-growth oak forest (mesic to dry, without pine) in Michigan
- 99.95% loss of mature to old-growth mesic beech-maple forest in Michigan
- 71% loss of wetlands in Michigan
- 50% loss of wetlands in Michigan between 1780s and 1980s
- 80% loss of southern tamarack swamp in Michigan between 1966 and 1980; only 4,400 acres remain in southern Lower Michigan
- 60-70% loss of coastal marsh in Michigan by 1980s; more developed since

Minnesota

- Overall Risk to Ecosystems: High

- Number of Listed Species: 11
- Number of Candidate Species: 56
- Number of Imperiled Vertebrates: 2
- Number of Imperiled Plants: 11
- Population density, 1992: 52.94 people per square mile
- Percent change in population density, 1982-1992: 8.13
- Percent of state developed as of 1992: 4.5
- Percent increase in developed land, 1982-1992: 11.0

FACTS

- >99% loss of original tallgrass prairie in Minnesota; probably over half of remainder in tracts <100 acres, over 75% in tracts <640 acres, few tracts >1,000 acres, and none >2,500 acres
- 99.98% of oak savanna in Minnesota destroyed; remaining 1,250 acres all on wind-modified outwash or fluvial sands
- 78% of aspen parkland in Minnesota destroyed
- 70% loss of presettlement jack pine forest in Minnesota
- 86% loss of red and white pine forest acreage in Minnesota, and much of remainder is in red pine plantations
- 72% loss of northern hardwood forest in Minnesota
- 57% loss of swamp conifer forest in Minnesota
- 50% loss of wetlands in Minnesota between 1780s and 1980s

Mississippi

- Overall Risk to Ecosystems: High
- Number of Listed Species: 38
- Number of Candidate Species: 77
- Number of Imperiled Vertebrates: 21
- Number of Imperiled Plants: 30
- Population density, 1992: 54.83 people per square mile
- Percent change in population density, 1982-1992: 1.87
- Percent of state developed as of 1992: 4.4
- Percent increase in developed land, 1982-1992: 12.1

FACTS

- Loss of all but a few small remnants of Black Belt prairie and Jackson Prairie in Mississippi to agriculture
- 50% of mainland shoreline of Mississippi altered by seawall construction and artificial beach nourishment
- 59% loss of wetlands in Mississippi between 1780s and 1980s

Missouri

- Overall Risk to Ecosystems: High
- Number of Listed Species: 22
- Number of Candidate Species: 86
- Number of Imperiled Vertebrates: 11
- Number of Imperiled Plants: 28
- Population density, 1992: 74.48 people per square mile
- Percent change in population density, 1982-1992: 5.04
- Percent of state developed as of 1992: 5.2
- Percent increase in developed land, 1982-1992: 9.5

FACTS

- 99.5% loss of original 15 million acres of tallgrass prairie in Missouri
- 99.98% of oak savanna in Missouri destroyed or degraded by fire suppression; an undetermined acreage of degraded savanna is restorable
- 95.9% of lowland forest in southeastern Missouri destroyed; more has been lost since 1977
- 90% loss of wetlands in Missouri

- 87% loss of wetlands in Missouri between 1780s and 1980s; much of what remains is of low quality with altered hydrology

Montana

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 12
- Number of Candidate Species: 65
- Number of Imperiled Vertebrates: 7
- Number of Imperiled Plants: 20
- Population density, 1992: 5.59 people per square mile
- Percent change in population density, 1982-1992: 2.11
- Percent of state developed as of 1992: 1.2
- Percent increase in developed land, 1982-1992: 8.1

■ FACTS

- 80-90% loss of low-elevation, high productivity, old growth forests in western Montana
- 80-90% loss of low-elevation native grasslands in western Montana
- 27% loss of wetlands in Montana between 1780s and 1980s
- 80-90% loss of woody hardwood draws in eastern Montana; glacial pothole ponds in Mission and Swan Valleys, on the Blackfeet Reservation, and in the northeastern prairie pothole region; and peatlands in Montana
- 95% of native waters in Montana have experienced declines or losses of native species and invasion of exotics

Nebraska

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 11
- Number of Candidate Species: 44
- Number of Imperiled Vertebrates: 7
- Number of Imperiled Plants: 9
- Population density, 1992: 20.7 people per square mile
- Percent change in population density, 1982-1992: 0.76
- Percent of state developed as of 1992: 2.5
- Percent increase in developed land, 1982-1992: 3.1

■ FACTS

- >97% loss of tallgrass prairie that once covered the eastern third of Nebraska
- 35% loss of wetlands in Nebraska between 1780s and 1980s
- >90% of original wetlands and 78% of original wetland acres destroyed in Rainwater Basin of south-central Nebraska
- 90% loss of eastern Nebraska saline wetlands in Lancaster and Saunders counties

Nevada

- Overall Risk to Ecosystems: High
- Number of Listed Species: 33
- Number of Candidate Species: 257
- Number of Imperiled Vertebrates: 29
- Number of Imperiled Plants: 200
- Population density, 1992: 12.08 people per square mile
- Percent change in population density, 1982-1992: 52.16
- Percent of state developed as of 1992: 0.6
- Percent increase in developed land, 1982-1992: 26.3

■ FACTS

- 52% loss of wetlands in Nevada between 1780s and 1980s
- 93.3% loss of marshes (from 79,000 acres to 5,300 acres) in Carson-Truckee area of western Nevada

New Hampshire

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 10
- Number of Candidate Species: 26
- Number of Imperiled Vertebrates: 1
- Number of Imperiled Plants: 14
- Population density, 1992: 120.18 people per square mile
- Percent change in population density, 1982-1992: 17.62
- Percent of state developed as of 1992: 9.5
- Percent increase in developed land, 1982-1992: 37.0

■ FACTS

- >50% loss of pitch pine-scrub oak barrens in New Hampshire; one of two remaining large occurrences has suffered 95% destruction
- >99% loss of virgin or old growth forests in New Hampshire
- 95% loss of floodplain forests in New Hampshire
- >50% loss or serious degradtion of dry pitch pine-red pine transitional oak forest, dry rich Appalachian oak-hickory forest, alpine/subalpine rocky summit, dry sandy riverbluff, inland beach strand, inland dune, coastal beach strand, coastal dune, interdunal swale, maritime forest on dunes, coastal plain pondshores (inland basin marsh and sandy pondshores), Atlantic white cedar swamp, black gum-red maple basin swamp, calcareous fen, calcareous circumneutral seepage swamp, fresh/brackish intertidal flat, moderately alkaline pond

New Jersey

- Overall Risk to Ecosystems: High
- Number of Listed Species: 19
- Number of Candidate Species: 53
- Number of Imperiled Vertebrates: 5
- Number of Imperiled Plants: 29
- Population density, 1992: 1004.17 people per square mile
- Percent change in population density, 1982-1992: 5.28
- Percent of state developed as of 1992: 31.9
- Percent increase in developed land, 1982-1992: 23.1

■ FACTS

- 37% loss of New Jersey pine barrens
- 39% loss of wetlands in New Jersey between 1780s and 1980s

New Mexico

- Overall Risk to Ecosystems: High
- Number of Listed Species: 37
- Number of Candidate Species: 142
- Number of Imperiled Vertebrates: 20
- Number of Imperiled Plants: 109
- Population density, 1992: 13.01 people per square mile
- Percent change in population density, 1982-1992: 15.73
- Percent of state developed as of 1992: 1.1
- Percent increase in developed land, 1982-1992: 22.8

■ FACTS

- 90% loss of presettlement riparian ecosystems in Arizona and New Mexico
- 33% loss of wetlands in New Mexico between 1780s and 1980s

New York

- Overall Risk to Ecosystems: High

- Number of Listed Species: 22
- Number of Candidate Species: 73
- Number of Imperiled Vertebrates: 9
- Number of Imperiled Plants: 29
- Population density, 1992: 368.76 people per square mile
- Percent change in population density, 1982-1992: 3.07
- Percent of state developed as of 1992: 9.6
- Percent increase in developed land, 1982-1992: 8.0

■ FACTS

- >90% of coastal heathland in southern New England and Long Island destroyed since mid-1800s
- >99.9% loss of Hempstead Plains grassland, Long Island, New York
- >98% probable loss of serpentine barrens, maritime heathland, and pitch pine-heath barrens in New York
- >90% probable loss of coastal plain Atlantic white cedar swamp, maritime oak-holly forest, maritime red cedar forest, marl fen, marl pond shore, oak openings
- 70-90% probable loss of alvar grassland, calcareous pavement barrens, coastal plain poor fens, dwarf pine ridges, inland Atlantic white cedar swamp, freshwater tidal swamp, inland salt marsh, mountain spruce-fir forest, patterned peatland, perched bog, pitch pine-blueberry peat swamp, rich graminoid fens, rich sloping fens, riverside ice meadow
- 50% or less loss of Allegheny oak forest, alpine krummholz, Great Lakes dunes, ice cave talus communities, perched swamp white oak swamp, rich shrub fen, sandstone pavement barrens
- 60-68% loss of Long Island pine barrens
- 60% loss of wetlands in New York between 1780s and 1980s
- 50-70% loss of coastal-plain ponds and pond shores in New York
- 50-70% loss of brackish intertidal mudflats, brackish intertidal shores, coastal plain streams

North Carolina

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 58
- Number of Candidate Species: 208
- Number of Imperiled Vertebrates: 25
- Number of Imperiled Plants: 93
- Population density, 1992: 129.79 people per square mile
- Percent change in population density, 1982-1992: 13.65
- Percent of state developed as of 1992: 10.5
- Percent increase in developed land, 1982-1992: 36.2

■ FACTS

- 90% loss of mountain bogs (Southern Appalachian bogs and swamp forest-bog complex, from 5000 to 500 acres) in North Carolina
- 69% loss of pocosins in North Carolina between 1952 and 1979 (33% converted to non-wetland uses; another 36% drained, cleared, or cut)
- 98-99% loss of Atlantic white cedar stands in the Great Dismal Swamp of Virginia and North Carolina, and probably across its range as a whole
- 49% loss of wetlands in North Carolina between 1780s and 1980s

North Dakota

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 10
- Number of Candidate Species: 34
- Number of Imperiled Vertebrates: 6
- Number of Imperiled Plants: 5
- Population density, 1992: 8.97 people per square

mile

- Percent change in population density, 1982-1992: -5.65
- Percent of state developed as of 1992: 3.0
- Percent increase in developed land, 1982-1992: 8.6

■ FACTS

- 90% loss of native grassland in North Dakota
- 49% loss of wetlands in North Dakota between 1780s and 1980s
- 60% of the original wetlands acreage in North Dakota drained

Ohio

- Overall Risk to Ecosystems: High
- Number of Listed Species: 18
- Number of Candidate Species: 63
- Number of Imperiled Vertebrates: 5
- Number of Imperiled Plants: 12
- Population density, 1992: 266.66 people per square mile
- Percent change in population density, 1982-1992: 2.3
- Percent of state developed as of 1992: 13.5
- Percent increase in developed land, 1982-1992: 15.3

■ FACTS

- 99.5-99.7% loss of prairies in Ohio since settlement
- >85% of original forest acreage in Ohio between settlement and 1939, followed by recovery to about 27% of total land area (28% of total acreage) by 1977; only a few small patches of old growth remain
- 90% loss of wetlands in Ohio from 1780s to 1980s
- 57% decline in forested wetlands in Ohio since 1940
- 25% of Ohio's fens destroyed

Oklahoma

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 17
- Number of Candidate Species: 63
- Number of Imperiled Vertebrates: 16
- Number of Imperiled Plants: 22
- Population density, 1992: 45.81 people per square mile
- Percent change in population density, 1982-1992 - -0.8
- Percent of state developed as of 1992: 4.2
- Percent increase in developed land, 1982-1992: 9.2

■ FACTS

- 82% loss of bottomland hardwood forests of eastern Oklahoma
- 67% loss of wetlands in Oklahoma between 1780s and 1980s

Oregon

- Overall Risk to Ecosystems: High
- Number of Listed Species: 32
- Number of Candidate Species: 237
- Number of Imperiled Vertebrates: 25
- Number of Imperiled Plants: 140
- Population density, 1992: 30.62 people per square mile
- Percent change in population density, 1982-1992: 11.39
- Percent of state developed as of 1992: 1.8
- Percent increase in developed land, 1982-1992: 17.1

■ FACTS

- >90% loss of native shrub-steppe grassland in Oregon and southwestern Washington
- 99.9% of Palouse prairie throughout range in Washington, Oregon, and Idaho lost to agriculture
- 83-90% loss of old-growth forests in Douglas-fir region of Oregon and Washington
- 96% of original coastal temperate rainforests in Oregon logged
- 92-98% loss of old-growth ponderosa pine forests in three sample national forests (Deschutes, Winema, and Fremont) in Oregon
- 99.5% loss of native grasslands and oak savannas in Willamette Valley, Oregon, since European settlement
- 99.9% loss of native prairie (all types combined) in Willamette Valley, Oregon, since European settlement
- 38% loss of wetlands in Oregon between 1780s and 1980s
- 85% loss of marshlands in Coos Bay area of Oregon

Pennsylvania

- Overall Risk to Ecosystems: High
- Number of Listed Species: 10
- Number of Candidate Species: 84
- Number of Imperiled Vertebrates: 6
- Number of Imperiled Plants: 27
- Population density, 1992: 264.74 people per square mile
- Percent change in population density, 1982-1992: 0.98
- Percent of state developed as of 1992: 11.8
- Percent increase in developed land, 1982-1992: 14.6

■ FACTS

- 10-50% loss of temperate eastern serpentine barrens (distributed from Georgia piedmont to New York, but most in Pennsylvania and Maryland) and Pocono till barrens (Pennsylvania)
- 56% loss of wetlands in Pennsylvania between 1780s and 1980s
- 20% of 23,833 miles of assessed streams in Pennsylvania degraded due to resource extraction (54.2%), agriculture (13.3%), and municipal point sources (9.2%)

Rhode Island

- Overall Risk to Ecosystems: High
- Number of Listed Species: 16
- Number of Candidate Species: 18
- Number of Imperiled Vertebrates: 4
- Number of Imperiled Plants: 9
- Population density, 1992: 825.57 people per square mile
- Percent change in population density, 1982-1992: 5.04
- Percent of state developed as of 1992: 24.5
- Percent increase in developed land, 1982-1992: 15.9

■ FACTS

- 37% loss of wetlands in Rhode Island between 1780s and 1980s

South Carolina

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 38
- Number of Candidate Species: 117
- Number of Imperiled Vertebrates: 15
- Number of Imperiled Plants: 72
- Population density, 1992: 115.81 people per square mile

- Percent change in population density, 1982-1992: 11.69
- Percent of state developed as of 1992: 9.3
- Percent increase in developed land, 1982-1992: 28.1

■ FACTS

- 27% loss of wetlands in South Carolina between 1780s and 1980s

South Dakota

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 10
- Number of Candidate Species: 41
- Number of Imperiled Vertebrates: 6
- Number of Imperiled Plants: 4
- Population density, 1992: 9.18 people per square mile
- Percent change in population density, 1982-1992: 2.02
- Percent of state developed as of 1992: 2.3
- Percent increase in developed land, 1982-1992: 5.9

■ FACTS

- 47% loss of native grassland in South Dakota by 1977, with significant but undocumented losses since then; bluestem prairie has declined by about 85% and wheatgrass-bluestem-needlegrass prairie by about 70%
- 35% loss of wetlands in South Dakota between 1780s and 1980s
- 40% of original wetland acreage in South Dakota drained

Tennessee

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 79
- Number of Candidate Species: 201
- Number of Imperiled Vertebrates: 49
- Number of Imperiled Plants: 64
- Population density, 1992: 119.23 people per square mile
- Percent change in population density, 1982-1992: 7.86
- Percent of state developed as of 1992: 8.0
- Percent increase in developed land, 1982-1992: 25.2

■ FACTS

- 95% loss of old-growth forests in the Cumberland Plateau
- 80-90% loss of old-growth forest in Blue Ridge province
- 100% of spruce-fir forest in Tennessee has been severely degraded from balsam wooly adelgid infestation and probable air pollution effects, although only 10-20% of the habitat area has been lost
- 50-60% conversion of Appalachian cove hardwood forests in the Blue Ridge province of Tennessee to non-forest habitats
- 60-70% conversion of mixed mesophytic forest on Cumberland Plateau of Tennessee to non-forest uses
- 60% loss of oak-hickory forests on the Cumberland Plateau and Highland Rim of Tennessee; of the remaining 40%, <5% is of high quality
- >90% loss of upland hardwoods in coastal plain of Tennessee; only one high-quality example remains
- 90% loss of ecologically intact limestone cedar glades in Tennessee
- 50% loss of total cedar glade acreage in Tennessee
- 60% loss of bottomland hardwood forests in Tennessee; remaining high quality stands are mostly on wetter sites
- 60-75% loss of cypress-tupelo forest in the coastal plain and Mississippi Alluvial Plain of

Tennessee

- 80-90% loss of upland wetlands in Highland Rim of Tennessee
- >90% loss of Appalachian bog in Blue Ridge province of Tennessee
- 59% loss of wetlands in Tennessee between 1780s and 1980s
- >90% loss of aquatic mussel beds in Tennessee, mostly due to impoundment but continuing declines due to changes in water chemistry

Texas

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 72
- Number of Candidate Species: 325
- Number of Imperiled Vertebrates: 43
- Number of Imperiled Plants: 222
- Population density, 1992: 66.28 people per square mile
- Percent change in population density, 1982-1992: 15.21
- Percent of state developed as of 1992: 4.8
- Percent increase in developed land, 1982-1992: 20.5

■ FACTS

- 99.9% loss of prairie in Texas
- 85% loss of natural longleaf pine forests in Texas and Louisiana since 1935
- 89% of 3.5 million acres of virgin forest in Big Thicket, Texas lost by 1960s
- 95% loss of native habitat in lower delta of Rio Grande River, Texas; what remains is highly fragmented
- 93% loss of seagrass meadows in Galveston Bay
- 52% loss of wetlands in Texas from 1780s to 1980s

Utah

- Overall Risk to Ecosystems: High
- Number of Listed Species: 38
- Number of Candidate Species: 212
- Number of Imperiled Vertebrates: 17
- Number of Imperiled Plants: 212
- Population density, 1992: 21.33 people per square mile
- Percent change in population density, 1982-1992: 15.28
- Percent of state developed as of 1992: 1.0
- Percent increase in developed land, 1982-1992: 23.6

■ FACTS

- 30% loss of wetlands in Utah between 1780s and 1980s

Vermont

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 7
- Number of Candidate Species: 20
- Number of Imperiled Vertebrates: 1
- Number of Imperiled Plants: 12
- Population density, 1992: 59.39 people per square mile
- Percent change in population density, 1982-1992: 9.81
- Percent of state developed as of 1992: 5.3
- Percent increase in developed land, 1982-1992: 25.1

■ FACTS

- 97% loss to development of pine-oak-heath sandplain woods in Lake Champlain basin of Vermont; remaining parcels degraded due to fire suppression
- Almost total loss of lake sand beach in Vermont;

only 6 degraded and fragmented examples known to exist
- 35% loss of wetlands in Vermont between 1780s and 1980s

Virginia

- Overall Risk to Ecosystems: Extreme
- Number of Listed Species: 52
- Number of Candidate Species: 159
- Number of Imperiled Vertebrates: 28
- Number of Imperiled Plants: 59
- Population density, 1992: 156.84 people per square mile
- Percent change in population density, 1982-1992: 16.55
- Percent of state developed as of 1992: 8.4
- Percent increase in developed land, 1982-1992: 25.7

■ FACTS

- >90% loss of pocosins in Virginia
- 98-99% loss of Atlantic white cedar stands in the Great Dismal Swamp of Virginia and North Carolina, and probably across its range as a whole
- 42% loss of wetlands in Virginia between 1780s and 1980s
- 95% loss of ultramafic soligenous wetlands in The Glades region of Virginia

Washington

- Overall Risk to Ecosystems: High
- Number of Listed Species: 22
- Number of Candidate Species: 98
- Number of Imperiled Vertebrates: 15
- Number of Imperiled Plants: 72
- Population density, 1992: 75.48 people per square mile
- Percent change in population density, 1982-1992: 20.28
- Percent of state developed as of 1992: 4.2
- Percent increase in developed land, 1982-1992: 18.4

■ FACTS

- 99.9% of Palouse prairie throughout its range in Washington, Oregon, and Idaho lost to agriculture
- 75% of original coastal temperate rainforests in Washington logged
- 28% of Washington's native vegetation "destroyed" (i.e., altered or covered with soil profiles), with greatest losses in the Palouse (74%), Northern and Southern Puget Lowlands (51% and 49%, respectively), Yakima Folds (47%) and Scabland Basins (47%) regions
- 70% loss of marshlands in Puget Sound and 50% in Willapa Bay areas of Washington
- 31% loss of wetlands in Washington between 1780s and 1980s
- 33% loss of wetlands in Washington by 1980s
- >90% loss of native shrub-steppe grassland in Oregon and southwestern Washington
- 83-90% loss of old-growth forests in Douglas-fir region of Oregon and Washington

West Virginia

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 18
- Number of Candidate Species: 97
- Number of Imperiled Vertebrates: 6
- Number of Imperiled Plants: 30
- Population density, 1992: 74.66 people per square mile
- Percent change in population density, 1982-1992: -7.75
- Percent of state developed as of 1992: 4.4

- Percent increase in developed land, 1982-1992: 19.8

■ FACTS

- 88-90% loss of red spruce forest (spruce-fir communities)
- 24% loss of wetlands in West Virginia between 1780s and 1980s
- Nearly total loss of free-flowing rivers in West Virginia; of major streams, only the Greenbrier River remains undammed
- 88% loss of spruce-fir forest in West Virginia, compared to 35-57% loss for southern Appalachians
- Almost total loss of bottomland hardwood forests in Ohio, lower Kanawha, and lower Monongahela River valleys in West Virginia

Wisconsin

- Overall Risk to Ecosystems: High
- Number of Listed Species: 16
- Number of Candidate Species: 61
- Number of Imperiled Vertebrates: 6
- Number of Imperiled Plants: 9
- Population density, 1992: 88.92 people per square mile
- Percent change in population density, 1982-1992: 5.23
- Percent of state developed as of 1992: 6.6
- Percent increase in developed land, 1982-1992: 11.9

■ FACTS

- >99.996% loss of high quality savanna in Wisconsin
- 46% loss of wetlands in Wisconsin from 1780s to 1980s
- >99% loss of original sedge meadows in Wisconsin

Wyoming

- Overall Risk to Ecosystems: Moderate
- Number of Listed Species: 11
- Number of Candidate Species: 96
- Number of Imperiled Vertebrates: 10
- Number of Imperiled Plants: 45
- Population density, 1992: 4.75 people per square mile
- Percent change in population density, 1982-1992: -8.82
- Percent of state developed as of 1992: 0.9
- Percent increase in developed land, 1982-1992: 8.0
- 38% loss of wetlands in Wyoming between 1780s and 1980s

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Table 1. Ecosystem types (plant communities and habitats) that have reportedly declined by 98 percent or more in the United States since European settlement (from Noss, LaRoe and Scott 1995).

Old growth and other virgin stands in the eastern deciduous forest biome
Spruce-fir forest in the southern Appalachians
Red and white pine forests (mature and old growth) in Michigan
Longleaf pine forests and savannas in the southeastern coastal plain
Pine rockland habitat in south Florida
Loblolly/shortleaf pine-hardwood forests in the west gulf coastal plain
Arundinaria gigantea canebrakes in Southeast
Tallgrass prairie east of Missouri River and on mesic sites across range
Bluegrass savanna-woodland and prairies in Kentucky
Black Belt prairies in Alabama and Mississippi and Jackson Prairie in Mississippi
Ungrazed dry prairie in Florida
Oak savanna in Midwest
Wet and mesic coastal prairies in Louisiana
Lakeplain wet prairie in Michigan
Sedge meadows in Wisconsin
Hempstead Plains grasslands on Long Island, New York
Lake sand beaches in Vermont
Serpentine barrens, maritime heathland and pitch pine-heath barrens in New York
Prairies (all types) and oak savannas in Willamette Valley and foothills of Coast Range, Oregon
Palouse prairie (Washington, Oregon and Idaho, plus similar communities in Montana)
Native grasslands (all types) in California
Alkali sink scrub in southern California
Coastal strand in southern California
Ungrazed sagebrush steppe in Intermountain West
Basin big sagebrush in Snake River Plain of Idaho
Atlantic white cedar stands in the Great Dismal Swamp of Virginia and North Carolina, and possibly across entire range
Streams in Mississippi Alluvial Plain

Table 2.

Some of the rarest plant communities in the conterminous United States grouped by major region of occurrence and listing the states in which each community occurs. Adapted from a 1994 report by the Natural Heritage Network and The Nature Conservancy, "Rare Plant Communities of the Conterminous United States," authored by D.H. Grossman, K.L. Goodin and C.L. Reuss. These communities are considered critically imperiled globally (rank "G1," "GQ" or "G?") by The Nature Conservancy.

Community Common Name	States
EAST	
American Beech/Greenbrier Forest (Maritime Beech Forest)	MA, NY
American Burnet-Big Leaved Grass of Parnassus-Few Headed Sneezeweed Shrubland (Oligotrophic Saturated Bog)	VA
Beach Heather-Silverling Dwarf Shrubland (Riverwash Hudsonia Sand/Gravel Barren)	ME, NH
Big Bluestem-Indian Grass-Star Grass-Wild Indigo Herbaceous Vegetation (Hempstead Plains Grassland)	NY
Grey Birch/Beach Heather-Sundial Lupine Sparse Woodland (Dry Riverbluff Opening Community)	NH
Ninebark/Bluejoint-Hemlock Parsley Sparse Shrubland (Eutrophic Saturated Scrub)	VA
Pitch Pine-Black Jack Oak/Broom Crowberry Shrubland (Pine Plains)	NJ
Pitch Pine/Huckleberry Shrubland (Dwarf Pine Ridges)	NY
Pitch Pine/Scrub Oak-Rhodora Sparse Woodland (Mesic Scrub Oak-Heath Barren)	PA, NY?, WV?*
Red Cedar/Fimbristylis-Eastern Prickly Pear Sparse Woodland (Submesotrophic Herbaceous Vegetation)	VA
Red Cedar-Post Oak/Painted Cup Sparse Woodland (Mesotrophic Scrub)	VA
Red Maple-Sweet Gum-Swamp Cottonwood Forest (Cape May Lowland Swamp)	NJ
Salt Marsh Bulrush-Foxtail Barley-Spike Rush Herbaceous Vegetation (Eutrophic Seasonally Flooded Herbaceous Vegetation)	VA
Virginia Pine-Pitch Pine/Little Bluestem-Carolina Whipgrass Sparse Woodland (Eastern Serpentine Barrens)	MD, PA
Wax Myrtle/Ten-Angled Pipewort-Beaked Spikerush Sparse Shrubland (Oligotrophic Saturated Scrub)	VA
White Pine/Ninebark/Alder Leaved Buckthorn/Big Leaved Grass of Parnassus Woodland(Oligotrophic Saturated Scrub)	VA

* Question marks indicate probable but unconfirmed occurrence.

(Table 2. continued)

SOUTHEAST	
Appalachian Gametophyte-Cave Alumroot-Michaux's Bluet Herbaceous Vegetation (Southern Blue Ridge Spray Cliff)	GA, NC, SC
Forested Canebrake	AR, GA, KY, MS,VA?
Fraser Fir Forest	NC, TN, VA
Little Bluestem-Bushy Broomsedge-Cherokee Sedge Herbaceous Vegetation (Cook Mountain Calcareous Prairie)	LA
Little Bluestem-Bushy Broomsedge-Missouri Coneflower Herbaceous Vegetation (Fleming Calcareous Prairie)	LA
Longleaf Pine-Shortleaf Pine/Little Bluestem Serpentine Woodland (Longleaf Pine Serpentine Woodland)	GA
Mountain Laurel/Little Bluestem/Lichen Sparse Shrubland (High Elevation Mafic Glade)	NC, VA?
Nutmeg Hickory-Water Hickory/Dwarf Palmetto Forest (Wet Marl Forest)	NC, SC
Pitch Pine-Black Gum/Netted Chainfern-Mountain Sweet Pitcher Plant Sparse Woodland (Southern Appalachian Bog)	NC
Pond Pine/Switch Cane Sparse Woodland (Peatland Canebrake)	NC, SC?, VA?
Red Spruce/Carolina Sheepkill/Gray's Lily Sparse Woodland (Southern Appalachian Bog)	NC, TN?, VA?
Red Spruce/Long-Stalked Holly-(Cranberry)/Kidneyleaf Grass of Parnassus/ Warnstorf's Peatmoss Sparse Woodland (Southern Appalachian Bog)	NC, VA?
Red Spruce/Long-Stalked Holly/Three-Seeded Sedge Woodland (Southern Appalachian Swamp Forest-Bog Complex [Spruce Subtype])	NC, VA
South Florida Slash Pine/Silver Palm-Brittle Thatch Palm Woodland (Florida Keys Pine Rockland)	FL
South Florida Slash Pine/Tetrazygia Woodland (Miami Rock Ridge Pine Rockland)	FL
Tag Alder-Smooth Azalea/Green Pitcher Plant-Fewflower Beaksedge Shrubland (Southern Appalachian Bog)	GA, NC
Texas Ebony-Anacua/Brazil Forest (Texas Ebony Forest)	TX, Mexico?
Texas Ebony-Snake Eyes Shrubland	TX, Mexico?
Texas Ebony-Snake Eyes-Spanish Digger Shrubland	TX, Mexico?
Texas Palmetto Wetland Forest (Mexican Palmetto Forest)	TX, Mexico
Tulip Tree/Poison Sumac-Great Laurel Sparse Woodland (Southern Appalachian Bog)	GA?, NC, TN, SC?, VA?

(Table 2. continued)

Twig Rush-Canada Burnet/Orange Peatmoss Herbaceous Vegetation (Southern Appalachian Fen)	NC
Virginia Pine-Pitch Pine/Little Bluestem-Platte Groundsel Sparse Woodland (Ultramafic Outcrop Barren)	NC, VA
Water Oak-Loblolly Pine/Carolina Jessamine Forest (Maritime Forest)	NC, VA, DE?
West Gulf Coastal Plain Nepheline Syenite Glade/Outcrop	AR
MIDWEST	
Alkali Bulrush-Spearscale-Spikerush Herbaceous Vegetation (Inland Salt Marsh)	IL, MI, NY
Beaked Willow-Willow Shrubland (Bebb's Willow Scrub)	SD, WY?
Beech-Sugar Maple-Sweetgum Crowley's Ridge Forest (Beech-Maple-Sweetgum Sand Forest)	AR, MO
Big Bluestem-Indian Grass-Porcupine Grass Loess Hills Herbaceous Vegetation (Big Bluestem Loess Hills Prairie)	IA, KS, MO, NE
Bur Oak-Pin Oak-Swamp White Oak/Bluejoint Grass Sparse Woodland (Lakeplain Wet-Mesic Oak Openings)	MI, OH?, Canada
Bur Oak/Mixed Grass Sand Sparse Woodland (Bur Oak Sand Savanna)	ND, SD
Bur Oak Shale Sparse Woodland (Bur Oak Shale Savanna)	SD
Bur Oak-Swamp White Oak-(Hackberry) River Terrace Woodland (Bur Oak Terrace Woodland)	IL, MO, WI?
Bur Oak-White Oak-Black Oak/Big Bluestem Sparse Woodland (Northern Oak Openings)	IA, IL, IN?, MI, MN, OH, WI, Canada?
Bur Oak-White Oak-Post Oak/Big Bluestem Sparse Woodland (Central Oak Openings)	IA, IL, IN?, MO, OH
Cottonwood-(Black Willow)/Cordgrass-Sedge Woodland (Cottonwood Wet Savanna)	KS, MO, NE, SD
Little Bluestem-Dropseed Chert Glade Herbaceous Vegetation (Chert Glade)	MO, OK?
Little Bluestem-Indian Grass-Three Awned Grass/Polypremum Sand Herbaceous Vegetation (Southern Sand Prairie)	AR, IL, IN, MO
Post Oak-Black Oak-White Oak-(Southern Red Oak)/Little Bluestem Sparse Woodland (Central Dry Mesic Barren)	AR, IL, KY, MO
Sedge-Bullrush Eastern Great Plains Seepage Herbaceous Vegetation (Eastern Great Plains Fen)	KS, NE

(Table 2. continued)

WEST	
American Dunegrass-Yellow Sandverbena Herbaceous Vegetation (American Dunegrass-Yellow Sandverbena Unstabilized Coastal Beach)	CA, OR, WA
Antelope Bitterbrush-Big Sagebrush Shrubland	ID
Antelope Bitterbrush/Bluebunch Wheatgrass-Basin	ID
Wildrye Sparse Shrubland Antelope Bitterbrush/Nevada Bluegrass Shrubland	ID
Antelope Bitterbrush-Rubber Rabbitbrush Shrubland	ID
Bigelove Nolina Shrubland	AZ?, CA, NV?
Big Sagebrush-Antelope Bitterbrush/Indian Ricegrass-Needle-and-Thread Sparse Shrubland	OR
Black Cottonwood/Douglas Hawthorn Forest	ID?, OR, WA?
Black Cottonwood/Water Hemlock Forest	ID, OR?, WA
Black Greasewood/Blue Grama Shrubland	NM
Black Greasewood/Bottlebrush Squirreltail-Western Wheatgrass Sparse Shrubland	NM
Bluebunch Wheatgrass-Idaho Fescue (Palouse) Herbaceous Vegetation	ID, OR, WA, Canada?
Border Pinyon/Gambel Oak Woodland	NM, Mexico?
California Oatgrass (Valley) Herbaceous Vegetation	OR
Contra Costa Wallflower-Antioch Dunes Evening Primrose Herbaceous Vegetation	CA
Curlleaf Mountain Mahogany-Oceanspray Shrubland	ID
Curly Bluegrass-Lemon's Alkaligrass-Bottlebrush Squirreltail Herbaceous Vegetation (Curly Bluegrass-Lemon's Alkaligrass-Bottlebrush Squirreltail Grassland)	OR
Cushion Wild Buckwheat Sparse Vegetation (Cushion Wild Buckwheat Cinder Gardens)	ID
(Cutting Wheatgrass)-Red Fescue-(Junegrass) Herbaceous Vegetation	OR
Douglas Fir/Common Snowberry-Creambush Oceanspray Forest	WA, Canada
Douglas Fir-Pacific Madrone/Creambush Oceanspray/ Hairy Honeysuckle Forest	WA, Canada
Emory Oak/Sand Dropseed Woodland	NM
Gowen Cypress Woodland	CA

(Table 2. continued)

Hinds Walnut Woodland	CA
Ione Manzanita Shrubland	CA
Island Oak Forest	CA, Mexico
Lemon Needlegrass/Silver Moss Herbaceous Vegetation	OR
Limber Pine/Antelope Bitterbrush Woodland	ID
Mesa Dropseed-Thin *Paspalum* Herbaceous Vegetation (Mesa Dropseed-Thin *Paspalum* Grassland)	NM, TX?
Monterey Cypress Woodland	CA
Monterey Pine Forest	CA
Mountain Alder-Black Cottonwood/Willow/Sedge Forest	OR
Mountain Big Sagebrush-Curl-leaf Mountain Mahogany/ Cutting Wheatgrass-Curly Bluegrass Shrubland	OR
New Mexico Saltbush/Alkali Sacaton-Sand Dropseed Dwarf Shrubland	NM
Oregon White Oak/Fescue Sparse Woodland	OR, WA
Oregon White Oak/Idaho Fescue Woodland	WA
Ponderosa Pine/Antelope Bitterbrush/Indian Ricegrass Woodland	OR
Ponderosa Pine-Douglas Fir Riparian Sparse Woodland	WA
Ponderosa Pine/Douglas Hawthorn Woodland	ID, OR, WA?
Ponderosa Pine/Indian Ricegrass Sparse Vegetation	CO, NM
Ponderosa Pine/Podfern Woodland	WA
Red Fescue Herbaceous Vegetation (Red Fescue Stabilized Dune Grasslands)	OR, WA
River Birch-Bitterbrush/Needle-and-Thread Shrubland	ID
Rubber Rabbitbrush/Sand Wildrye-Lanceleaf Scurf-Pea Shrubland	ID
Santa Cruz Cypress Woodland	CA
Screwbean Mesquite Shrubland	NM
Shore Pine/Salal-Rhododendron-Evergreen Huckleberry Woodland	CA?, OR
Sierra Blanca Cinquefoil Herbaceous Vegetation Sierra Blanca Cinquefoil Fellfield)	NM
Silver Sagebrush/Basin Wild Rye Sparse Shrubland	OR
Silver Sagebrush/(Cutting Wheatgrass)-Curly Bluegrass Sparse Shrubland	OR
Single-Leaf Pinyon Pine-Utah Juniper/Mountain Big Sagebrush/Bluebunch Wheatgrass Woodland	ID

(Table 2. continued)

Single-Leaf Pinyon Pine-Utah Juniper/Chokecherry Woodland	ID
Single-Leaf Pinyon Pine-Utah Juniper/Curl-leaf Mountain Mahogany/ Bluebunch Wheatgrass Woodland	ID
Single-Leaf Pinyon Pine-Utah Juniper/Great Basin Wildrye Woodland	ID
Smooth Sumac/Red Threeawn Shrubland	ID?, OR?, WA
Tecate Cypress Woodland	CA
Thickspike Wheatgrass-Needle and Thread Herbaceous Vegetation	OR
Threetip Sagebrush\Needle-and-Thread Sparse Shrubland	ID?, WA, Canada?
Torrey Pine Woodland	CA
Toumey Oak/Bullgrass Shrubland	AZ, NM, Mexico
Toumey Oak/Sideoats Grama Shrubland	AZ, NM, Mexico
Tufted Bulrush-Livid Sedge Herbaceous Vegetation	ID
Utah Juniper/Antelope Bitterbrush-Mountain Snowberry/Bluebunch Wheatgrass Woodland	ID
Utah Juniper/Needle and Thread Sparse Woodland	ID
Utah Juniper/Salmon River Rye Sparse Woodland	ID
Washoe Pine Woodland	CA, NV
Western Juniper/Big Sagebrush/Threadleaf Sedge Sparse Woodland	OR
Western Redcedar/Salal Forest	WA
Western Redcedar/Vanillaleaf Forest	WA, Canada
White Alder/River Birch Forest	ID, OR
White Alder/Mock Orange Forest	ID, OR?
White Alder/Woods Rose Forest	ID, OR?
White Fir-Colorado Blue Spruce-Narrowleaf Cottonwood/Rocky Mountain Maple Forest	CO, NM?
White Fir-Port Orford Cedar-Brewer Spruce/Huckleberry Oak Forest	CA?, OR

Table 3.

Land-type associations of 667 federally listed threatened and endangered species, from “Species Endangerment Patterns in the United States” (C.H. Flather, L.A. Joyce and C.A. Bloomgarden, USDA Forest Service GTR RM-241, 1994). Species can occur in more than one land type category.

Land Type	All T and E	Plants	Animals
FOREST	**312**	**109**	**203**
Deciduous	128	39	89
Evergreen	178	60	118
Mixed	110	34	76
RANGELAND	**271**	**125**	**146**
Herbaceous	101	41	60
Shrub/Brush	170	72	98
Mixed	85	25	60
BARREN	**176**	**96**	**80**
Beaches	35	3	32
Dry Salt Flats	17	8	9
Exposed Rock	81	58	23
Mines/Quarries/Pits	29	13	16
Sand (not beach)	43	22	21
Mixed	17	7	10
Transition	26	7	19
WATER	**244**	**24**	**220**
Bay/Estuary	38	2	36
Lakes	49	3	46
Reservoirs	61	4	57
Stream/Canal	217	22	195
WETLAND	**155**	**47**	**108**
Forested	71	16	55
Nonforested	121	37	84

Table 4. The 21 most-endangered ecosystems of the United States, based on rough calculations of extent of decline, present area (rarity), imminence of threat and number of federally listed threatened and endangered species associated with each type. Ranking criteria are listed below the table.

	Extent Decline	Present Area	Imminence of Threat	T and E Species	Total Score
South Florida Landscape	5	5	5	3	18
Southern Appalachian Spruce-Fir Forest	5	4	5	2	16
Longleaf Pine Forest and Savanna	5	2	4	5	16
Eastern Grassland, Savanna, and Barrens	3	3	4	5	15
Northwestern Grassland and Savanna	5	3	4	3	15
California Native Grassland	5	1	4	5	15
Coastal Communities in Lower 48 States and Hawaii	4	1	5	5	15
Southwestern Riparian Forest	3	3	4	5	15
Southern California Coastal Sage Scrub	3	2	4	5	14
Hawaiian Dry Forest	3	1	5	5	14
Large Streams and Rivers in Lower 48 States and Hawaii	4	1	4	5	14
Cave and Karst Systems	3	1	5	5	14
Tallgrass Prairie	4	1	4	4	13
California Riparian Forest and Wetlands	3	1	4	5	13
Florida Scrub	1	3	4	5	13
Ancient Eastern Deciduous Forest	5	1	2	4	12
Ancient Forest of Pacific Northwest	3	1	3	5	12
Ancient Red and White Pine Forest, Great Lakes States	5	3	2	1	11
Ancient Ponderosa Pine Forest	3	1	4	3	11
Midwestern Wetland	3	1	3	2	9
Southern Forested Wetland	1	1	3	3	8

(Table 4. continued)

Ranking Criteria for Endangered Ecosystems

In cases of great uncertainty or variation in status across the range of an ecosystem, a score between categories (e.g., 4) was given.

Extent of Decline

5 > 98% loss of area or significant degradation of ecological structure, function, or composition since European settlement
3 85-98% loss of area or significant degradation of ecological structure, function, or composition since European settlement
1 < 85% loss of area or significant degradation of ecological structure, function, or composition since European settlement

Present Areal Extent

5 ≤ 20 viable occurrences or ≤10,000 acres (corresponds to The Nature Conservancy's criteria for G1-G2 communities)
3 21-100 viable occurrences or 10,000-50,000 acres (corresponds to The Nature Conservancy's criteria for G3 communities)
1 ≥100 viable occurrences or ≥50,000 acres (corresponds to The Nature Conservancy's criteria for G4-G5 communities)

Imminence of Threat

5 At high risk of significant areal loss or degradation within the next 10 years due to development, resource extraction, pollution, consequences of fragmentation (edge effects, exotic invasions, etc.) or other factors
3 At moderate risk of significant areal loss or degradation within next 10 years, or at high risk over the next 50 years, due to factors noted above
1 At low risk of significant areal loss or degradation within next 10 years, but may be at moderate to high risk over a time period of 25 years or more

Number of Federally Listed or C1-C2 Candidate Species Associated with Type

5 ≥25 species
3 10-24 species
1 < 10 species

Table 5. Overall Risk Index (ORI, Map 1). This index was calculated by combining three factors: number of most-endangered ecosystems (ERI, Map 2), the percentage of species in the state that are imperiled (SRI, Map 3) and overall development pressure (DRI, Map 4). Values for ORI range from 6 to 23, with 23 signifiying the most extreme risk.

EXTREME RISK	
FL	23
CA	19
HI	19
GA	17
NC	17
TX	17
SC	16
VA	16
AL	15
TN	15

MODERATE RISK	
AR	10
NH	10
CO	8
IA	8
ID	8
ME	7
MT	7
NE	7
OK	7
SD	7
VT	7
WV	7
AK	6
KS	6
ND	6
WY	6

HIGH RISK	
NJ	14
OH	14
DE	13
IL	13
IN	13
MD	13
MI	13
MS	13
NV	13
AZ	12
KY	12
MA	12
OR	12
CT	11
LA	11
MN	11
MO	11
NM	11
NY	11
PA	11
RI	11
UT	11
WA	11
WI	11

Overall Risk Index with Subindices (States by Alphabetical Order)

Table 6.

	Overall Risk Index (ORI)	Species Risk Index (SRI)	Ecosystem Risk Index (ERI)	Development Risk Index (DRI)
AK	6	4	0	2
AL	15	6	7	2
AR	10	5	4	1
AZ	12	5	3	4
CA	19	7	7	5
CO	8	3	3	2
CT	11	2	4	5
DE	13	2	4	7
FL	23	7	8	8
GA	17	6	6	5
HI*	19	12	3	4
IA	8	2	5	1
ID	8	3	3	2
IL	13	4	6	3
IN	13	4	6	3
KS	6	2	2	2
KY	12	5	4	3
LA	11	4	6	1
MA	12	2	4	6
MD	13	2	4	7
ME	7	2	4	1
MI	13	3	7	3
MN	11	2	7	2
MO	11	4	5	2

*include 4 bonus points for extraordinary percentage and ecological uniqueness of endangered species and ecosystems

(Table 6. continued)

	Overall Risk Index (ORI)	Species Risk Index (SRI)	Ecosystem Risk Index (ERI)	Development Risk Index (DRI)
MS	13	5	6	2
MT	7	2	4	1
NC	17	5	7	5
ND	6	2	3	1
NE	7	3	3	1
NH	10	1	4	5
NJ	14	2	4	8
NM	11	5	3	3
NV	13	6	3	4
NY	11	3	5	3
OH	14	3	7	4
OK	7	4	2	1
OR	12	5	5	2
PA	11	3	5	3
RI	11	1	4	6
SC	16	5	6	5
SD	7	2	3	2
TN	15	6	5	4
TX	17	6	7	4
UT	11	6	3	2
VA	16	5	6	5
VT	7	1	3	3
WA	11	3	5	3
WI	11	2	7	2
WV	7	3	3	1
WY	6	3	3	0

Table 7.

Overall Risk Index (ORI) organized by regions. This table shows the information in Table 6 organized by geographic regions.

Overall Risk Region/State	Species Risk Index (ORI)	Ecosystem Risk Index (SRI)	Development Risk Index (ERI)	Index (DRI)
EAST REGION				
CT	11	2	4	5
DE	13	2	4	7
MA	12	2	4	6
MD	13	2	4	7
ME	7	2	4	1
NH	10	1	4	5
NJ	14	2	4	8
NY	11	3	5	3
PA	11	3	5	3
RI	11	1	4	6
VT	8	2	3	3
WV	7	3	3	1
PLAINS REGION				
KS	6	2	2	2
MT	7	2	4	1
ND	6	2	3	1
NE	7	3	3	1
OK	7	4	2	1
SD	7	2	3	2
WY	6	3	3	0
CO	8	3	3	2
IA	8	2	5	1
MIDWEST REGION				
IL	13	4	6	3
IN	13	4	6	3
MI	13	3	7	3
MN	11	2	7	2

(Table 7. continued)

Overall Risk Region/State	Species Risk Index (ORI)	Ecosystem Risk Index (SRI)	Development Risk Index (ERI)	Index (DRI)
MIDWEST REGION (CONTINUED)				
MO	11	4	5	2
OH	14	3	7	4
WI	11	2	7	2
SOUTH REGION				
AL	15	6	7	2
AR	10	5	4	1
FL	23	7	8	8
GA	17	6	6	5
KY	12	5	4	3
LA	11	4	6	1
MS	13	5	6	2
NC	17	5	7	5
SC	16	5	6	5
TN	15	6	5	4
VA	16	5	6	5
SOUTHWEST REGION				
AZ	12	5	3	4
CA	19	7	7	5
NM	11	5	3	3
NV	13	6	3	4
TX	17	6	7	4
UT	11	6	3	2
NORTHWEST REGION				
ID	8	3	3	2
OR	12	5	5	2
WA	11	3	5	3
HI	19*	12	3	4
AK	6	4	0	2

* Includes 4-point bonus

Table 8.

Calculation of Species Risk Index (SRI) (See Map 3). Columns A through D are the percent species in a state that are imperiled for four taxonomic groups: plants, vertebrates, mussels and crayfish. "Imperiled" means classified as G1 or G2 according to The Network of Natural Heritage Program and Conservation Data Centers and The Nature Conservancy. These organizations supplied the data for our analysis.

	%P	%V	%M	%C	Ps	Vs	PVs	IAs	Total	SRI
AK	3.1	2.0	0.0	0.0	4	3	4	NA	NA	4
AL	3.8	5.1	39.2	15.4	4	6	5	8	18	6
AR	1.3	2.7	25.9	29.1	2	3	3	8	13	5
AZ	5.9	2.4	0.0	0.0	6	3	5	NA	NA	5
CA	14.3	6.4	16.7	16.7	8	7	8	6	21	7
CO	3.7	1.1	0.0	0.0	4	2	3	NA	NA	3
CT	0.9	0.6	8.3	0.0	1	1	1	3	5	2
DE	1.4	0.7	7.7	0.0	2	1	2	3	6	2
FL	6.9	4.0	37.0	44.4	7	4	6	8	19	7
GA	4.7	3.8	30.3	16.4	5	4	5	8	17	6
HI	29.9	27.1	0.0	0.0	8	8	8	NA	NA	12*
IA	0.6	0.7	17.0	0.0	1	1	1	3	5	2
ID	2.3	1.8	0.0	0.0	3	2	3	NA	NA	3
IL	0.8	1.5	25.3	13.0	1	2	2	7	10	4
IN	0.7	1.5	24.4	31.3	1	2	2	8	11	4
KS	0.7	1.2	6.5	0.0	1	2	2	2	5	2
KY	1.5	2.6	23.8	22.0	2	3	3	8	13	5
LA	1.4	1.8	17.1	14.7	2	2	2	6	10	4
MA	1.3	1.3	3.0	0.0	2	2	2	1	5	2
MD	1.4	1.4	5.6	0.0	2	2	2	1	5	2
ME	1.2	1.1	0.0	0.0	2	2	2	1	5	2
MI	0.9	1.2	10.7	11.1	1	2	2	4	7	3
MN	0.6	0.3	12.5	0.0	1	1	1	3	5	2
MO	1.3	1.5	20.6	17.6	2	2	2	7	11	4
MS	1.3	2.6	23.8	23.0	2	3	3	8	13	5
MT	0.9	1.1	1.3	0.0	1	2	2	1	4	2
NC	3.2	2.8	28.2	26.7	4	3	4	8	15	5

* Includes 4 additional points for Hawaii's extraordinarily high number of endemic endangered species.

(Table 8. continued)

	%P	%V	%M	%C	Ps	Vs	PVs	AIs	Total	SRI
ND	0.4	1.1	0.0	0.0	1	2	2	1	4	2
NE	0.6	1.0	17.1	0.0	1	2	2	6	9	3
NH	0.9	0.2	9.1	0.0	1	1	1	NA	NA	1
NJ	1.3	0.8	8.3	0.0	2	1	2	3	6	2
NM	3.4	2.2	25.0	33.3	4	3	4	8	15	5
NV	7.0	4.0	0.0	0.0	8	4	6	NA	NA	6
NY	1.2	1.2	13.7	0.0	2	2	2	3	7	3
OH	0.6	0.8	24.4	11.1	1	1	1	6	8	3
OK	0.9	2.0	19.4	18.2	1	3	2	7	11	4
OR	4.5	3.3	11.1	0.0	5	4	5	4	13	5
PA	1.2	0.9	18.5	0.0	2	1	2	4	7	3
RI	0.6	0.9	0.0	0.0	1	1	1	1	3	1
SC	2.9	2.2	26.7	10.7	3	3	3	7	13	5
SD	0.3	1.0	3.4	0.0	1	2	2	2	5	2
TN	2.6	6.1	35.8	13.5	3	7	5	8	18	6
TX	5.0	4.0	26.7	16.7	5	4	5	8	17	6
UT	7.3	2.7	0.0	0.0	8	3	6	NA	NA	6
VA	2.2	3.4	29.1	4.5	3	4	4	6	13	5
VT	0.7	0.2	5.0	0.0	1	1	1	NA	NA	1
WA	3.0	2.4	0.0	0.0	4	3	4	1	8	3
WI	0.5	0.9	8.2	0.0	1	1	1	2	4	2
WV	1.6	1.0	18.6	10.5	2	2	2	5	9	3
WY	2.0	1.6	0.0	0.0	3	2	3	NA	NA	3

%P = Percent plant species in state that are imperiled.
%V = Percent vertebrate species in state that are imperiled.
%M = Percent mussel species in state that are imperiled.
%C = Percent crayfish species in state that are imperiled.
Ps = %P scaled from 1 to 8.
Vs = %V scaled from 1 to 8.
PVs = Ps and Vs summed and rescaled from 1 to 8.
AIs = Combined score for aquatic invertebrates (mussels and crayfish). This score was derived by adding the percentage of imperiled mussels to the percentage of imperiled crayfish and dividing by two. The resulting sums were scaled from 1 to 8. NA was assigned when there too few mussel and crayfish species to be considered in this calculation, in other words, when there were five or fewer species of each in a state.
Total = This score is the sum of Ps, Vs and AIs. If AIs was NA, this column is NA also.
SRI = This is the Species Risk Index which is combined with the Endangered Ecosystem Index and Development Risk Index to yield the Overall Risk Index (Table 6). The SRI was calculated by either a. rescaling all the Totals from 1 to 8 if the value in the Total column is numerical or b. using the PVs score if Total = NA.

Table 9.

Ecosystem Risk Index (ERI) (See Map 2). The Ecosystem Risk Index is a scaled score reflecting how many of the 21 most-endangered ecosytems from Table 4 occur in each state. Values range from 0 to 8, with 8 signifying the greatest risk.

State	Number of Top 21 Endangered Ecosystems	Ecosystem Risk Index (ERI)
AK	1	0
AL	8	7
AR	5	4
AZ	4	3
CA	8	7
CO	4	3
CT	5	4
DE	5	4
FL	9	8
GA	7	6
HI	4	3
IA	6	5
ID	4	3
IL	7	6
IN	7	6
KS	3	2
KY	5	4
LA	7	6
MA	5	4
MD	5	4
ME	5	4
MI	8	7
MN	8	7
MO	6	5
MS	7	6
MT	5	4
NC	8	7
ND	4	3
NE	4	3
NH	5	4
NJ	5	4
NM	4	3
NV	4	3
NY	6	5
OH	8	7
OK	3	2
OR	6	5
PA	6	5
RI	5	4
SC	7	6
SD	4	3
TN	6	5
TX	8	7
UT	4	3
VA	7	6
VT	4	3
WA	6	5
WI	8	7
WV	4	3
WY	4	3

Table 10. Development Status Subindex (See Map 5). This index combines four factors that indicate how severely a state had been developed as of 1992. They are: population density, percentage of state developed, percentage of state in farms, and rural road density in miles per acre. Data is from U.S. Bureau of the Census, 1994.

State	Population Density[1] in 1992	(Score)	Percentage of State Developed[2] in 1992	(Score)	Percentage of State in Farms in 1992	(Score)	Rural Road Density[3] in 1992	(Score)	Scaled Score Subtotal	Status Subindex
AK	1.03	1	no data	1	0.3	1	no data	1	4	1
AL	80.03	2	6.2	3	29.6	3	1.50	6	14	4
AR	45.01	1	3.9	2	45.5	4	1.36	5	12	4
AZ	33.61	1	1.9	1	49.3	4	0.37	2	8	2
CA	194.67	4	4.9	2	29.3	3	0.59	2	11	3
CO	33.29	1	2.5	1	49.2	4	0.64	3	9	3
CT	653.35	8	25.4	8	12.8	2	2.35	8	26	8
DE	337.85	7	15.7	6	42.8	4	2.13	8	25	8
FL	229.83	5	12.4	5	28.0	3	1.21	5	18	6
GA	114.97	3	8.2	3	32.1	3	1.56	6	15	5
HI	178.66	4	4.1	2	41.3	4	0.37	2	12	4
IA	49.81	1	4.9	2	92.7	8	1.93	7	18	6
ID	12.76	1	1.1	1	25.2	3	0.67	3	8	2
IL	206.10	5	8.6	3	78.8	7	2.02	7	22	7
IN	156.36	4	9.0	4	69.1	6	2.22	8	22	7
KS	30.57	1	3.8	2	90.8	8	1.57	6	17	5
KY	92.90	2	6.4	3	54.5	5	1.63	6	16	5
LA	89.61	2	5.8	2	28.5	3	1.03	4	11	3
MA	723.41	8	24.7	8	12.8	2	2.13	8	26	8
MD	470.03	8	16.4	6	32.9	3	1.78	6	23	7
ME	37.16	1	3.3	2	6.7	1	0.62	3	7	2
MI	161.19	4	9.8	4	28.8	3	1.70	6	17	5
MN	52.94	2	4.5	2	55.2	5	1.43	5	14	4
MO	74.48	2	5.2	2	67.9	6	1.61	6	16	5

1. People per square mile.
2. Includes urban and built-up areas of ten acres or greater.
3. Miles of rural road per square mile of undeveloped land.

(Table 10. continued)

State	Population Density [1] in 1992	(Score)	Percentage of State Developed in 1992	(Score)	Percentage of State in Farms in 1992	(Score)	Rural Road Density [2] in 1992	(Score)	Scaled Score Subtotal	Status Subindex
MS	54.83	2	4.4	2	41.9	4	1.42	5	13	4
MT	5.59	1	1.2	1	63.8	6	0.47	2	10	3
NC	129.79	3	10.5	4	28.2	3	1.57	6	16	5
ND	8.97	1	3.0	1	89.3	8	1.24	5	15	5
NE	20.70	1	2.5	1	95.1	8	1.16	4	14	4
NH	120.18	3	9.5	4	7.9	1	1.49	5	13	4
NJ	1004.17	8	31.9	8	17.7	2	2.22	8	26	8
NM	13.01	1	1.1	1	56.8	5	0.46	2	9	3
NV	12.08	1	0.6	1	12.6	2	0.37	2	6	2
NY	368.76	8	9.6	4	26.1	3	1.64	6	21	7
OH	266.66	6	13.5	5	58.2	5	2.30	8	24	8
OK	45.81	1	4.2	2	75.9	7	1.49	5	15	5
OR	30.62	1	1.8	1	28.2	3	0.90	3	8	2
PA	264.74	6	11.8	4	27.6	3	2.15	8	21	7
RI	825.57	8	24.5	8	8.1	1	1.66	6	23	7
SC	115.81	3	9.3	4	26.1	3	1.90	7	17	5
SD	9.18	1	2.3	1	89.6	8	1.08	4	14	4
TN	119.23	3	8.0	3	46.7	4	1.78	6	16	5
TX	66.28	2	4.8	2	76.1	7	0.86	3	14	4
UT	21.33	1	1.0	1	20.8	2	0.44	2	6	2
VA	156.84	4	8.4	3	33.3	3	1.41	5	15	5
VT	59.39	2	5.3	2	24.5	2	1.41	5	11	3
WA	75.48	2	4.2	2	36.7	3	0.96	4	11	3
WI	88.92	2	6.6	3	48.1	4	1.82	7	16	5
WV	74.66	2	4.4	2	23.9	2	1.37	5	11	3
WY	4.75	1	0.9	1	55.6	5	0.38	2	9	3

Table 11. Development Trend Subindex (See Map 6). This index provides a picture of how rapidly development was occurring in the decade 1982-1992. It is based on four factors: absolute number of people added per square mile during the decade, percent change in population density, the percent of the state developed during the decade and the percent increase in the total amount of developed land. Data is from U.S Bureau of the Census, 1994.

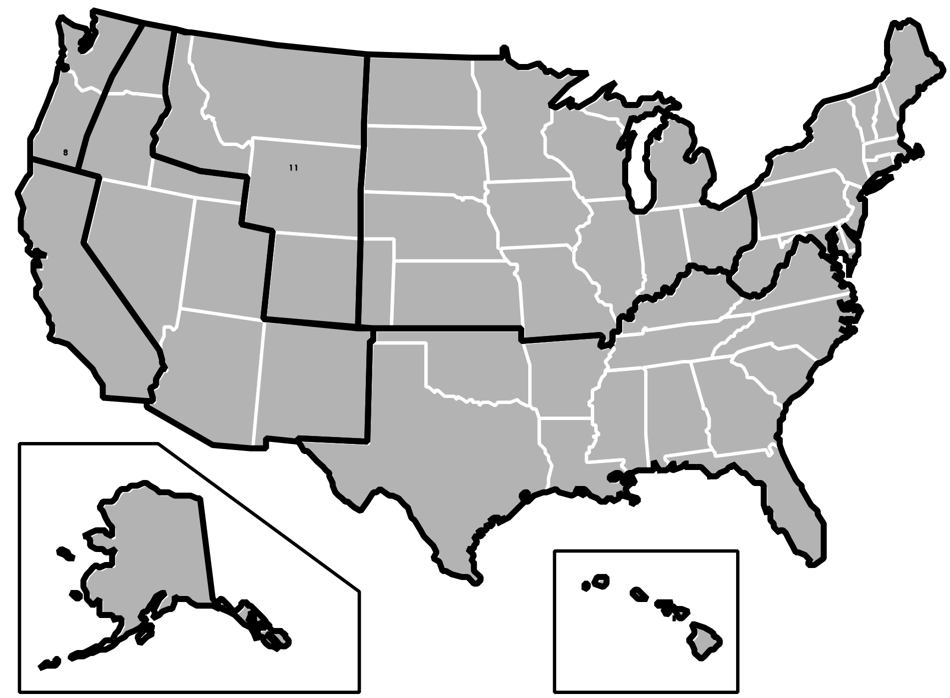
State	Number of People Added per Square Mile (From 1982 to 1992)	(Score)	Percent Change[1] in Population Density[2] (From 1982 to 1992)	(Score)	Percent of State Developed[3] (From 1982 to 1992)	(Score)	Percent Change[4] in the Amount of Developed Land in State (From 1982 to 1992)	(Score)	Score Subtotal	Trend Subindex
AK	0.25	1	32.43	7	no data	1	no data	4	13	4
AL	3.79	1	4.97	1	0.98	2	18.8	4	8	2
AR	1.64	1	3.77	1	0.28	1	7.9	2	5	1
AZ	8.25	2	32.55	7	0.50	1	35.1	8	18	6
CA	39.05	5	25.09	6	0.79	2	19.1	4	17	5
CO	3.79	1	12.87	3	0.47	1	22.4	5	10	3
CT	30.49	4	4.89	1	2.62	4	11.5	3	12	4
DE	44.49	6	15.17	4	2.67	4	20.6	5	19	6
FL	51.36	7	28.78	6	3.18	5	34.6	7	25	8
GA	19.05	3	19.85	4	2.02	3	32.8	7	17	5
HI	24.57	4	15.95	4	0.56	1	15.6	4	13	4
IA	-1.85	0	-3.58	0	0.14	1	2.9	1	2	1
ID	1.07	1	9.11	2	0.18	1	19.1	4	8	2
IL	2.61	1	1.28	1	0.67	1	8.4	2	5	1
IN	4.86	1	3.21	1	1.03	2	12.8	3	7	2
KS	1.31	1	4.49	1	0.23	1	6.5	2	5	1
KY	1.48	1	1.62	1	1.42	2	28.6	6	10	3
LA	-2.16	0	-2.35	0	0.88	2	18.1	4	6	2
MA	29.94	4	4.32	1	4.39	6	21.7	5	16	5
MD	61.66	8	15.10	4	2.23	3	15.8	4	19	6
ME	3.01	1	8.80	2	0.46	1	16.4	4	8	2
MI	5.45	1	3.50	1	1.23	2	14.3	3	7	2

1. This number was calculated by dividing the change in population density between 1982 and 1992 by the population density in 1982.
2. Number of people per square mile.
3. Includes urban and suburban areas of ten acres or more and does not include cropland, pasture land, rangeland or forest.
4. This number was calculated by dividing the change in the amount of developed land between 1982 and 1992 by the total amount of developed land in 1982.

(Table 11. continued)

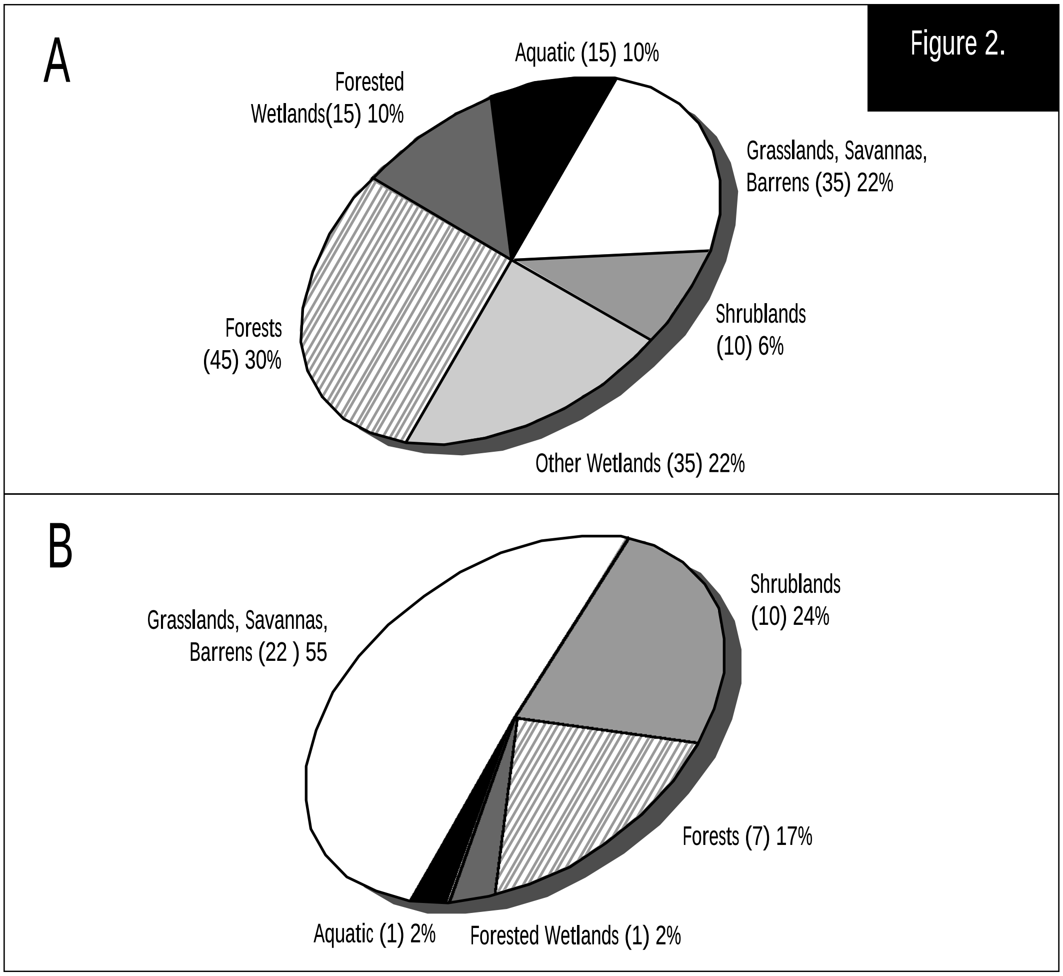
State	Number of People Added per Square Mile (From 1982 to 1992)	(Score)	Percent Change[1] in Population Density[2] (From 1982 to 1992)	(Score)	Percent of State Developed[3] (From 1982 to 1992)	(Score)	Percent Change[4] in the Amount of Developed Land in State (From 1982 to 1992)	(Score)	Score Subtotal	Trend Subindex
MN	3.98	1	8.13	2	0.44	1	11.0	3	7	2
MO	3.57	1	5.04	2	0.46	1	9.5	2	6	2
MS	1.01	1	1.87	1	0.47	1	12.1	3	6	2
MT	0.12	1	2.11	1	0.09	1	8.1	2	5	1
NC	15.59	2	13.65	3	2.79	4	36.2	8	17	5
ND	-0.54	0	-5.65	0	0.23	1	8.6	2	3	1
NE	0.16	1	0.76	1	0.08	1	3.1	1	4	1
NH	18.00	3	17.62	4	2.56	4	37.0	8	19	6
NJ	50.34	7	5.28	2	5.98	8	23.1	5	22	7
NM	1.77	1	15.73	4	0.21	1	22.8	5	11	3
NV	4.14	1	52.16	8	0.12	1	26.3	6	16	5
NY	11.00	2	3.07	1	0.71	1	8.0	2	6	2
OH	6.00	1	2.30	1	1.78	3	15.3	4	9	3
OK	-0.37	0	-0.80	0	0.35	1	9.2	2	3	1
OR	3.13	1	11.39	3	0.26	1	17.1	4	9	3
PA	2.56	1	0.98	1	1.50	3	14.6	3	8	2
RI	39.59	5	5.04	2	3.35	5	15.9	4	16	5
SC	12.12	2	11.69	3	2.04	3	28.1	6	14	4
SD	0.18	1	2.02	1	0.13	1	5.9	2	5	1
TN	8.68	2	7.86	2	1.61	3	25.2	6	13	4
TX	8.75	2	15.21	4	0.82	2	20.5	5	13	4
UT	2.83	1	15.28	4	0.20	1	23.6	5	11	3
VA	22.27	3	16.55	4	1.71	3	25.7	6	16	5
VT	5.30	1	9.81	2	1.06	2	25.1	6	11	3
WA	12.72	2	20.28	5	0.66	1	18.4	4	12	4
WI	4.42	1	5.23	2	0.70	1	11.9	3	7	2
WV	-6.27	0	-7.75	0	0.74	1	19.8	4	5	1
WY	-0.46	0	-8.82	0	0.06	1	8.0	2	3	1

Figure 1.



This map shows, for major regions of the United States, the number of ecosystems that have lost more than 70 percent of their original area. Data is from Appendix B of the National Biological Service report*. When an ecosystem overlaps two or more regions, each region was counted as containing that particular ecosystem. Regions with few imperiled ecosystems are not necessarily in better condition than those with many because numbers reflect sampling and reporting biases.

* Noss, R.F., E.T. LaRoe III and J.M. Scott. 1995.



(A) This figure shows the distribution according to general habitat type of 155 specific ecosystems that were identified in Appendix B of the National Biological Service report* as having lost more that 70 percent of their original area. General habitat types include "forests," "forested wetlands," "aquatic," "grasslands, savannas and barrens," "shrublands" and "other wetlands." For example, the habitat type "forests" contains spruce-fir forest in the southern Appalachians and 44 other forest ecosystems. The majority of imperiled ecosystems fall into the habitat types "forests," "other wetlands," and "grasslands, savannas and barrens." Wetland data were handled differently because data for individual ecosystems were often not available and what data exist are usually state-by-state for the general category "wetlands." Therefore, whenever wetland loss in a state exceeded 70 percent we counted this as one wetland ecosystem. **(B)** This figure uses the same methodology as Figure 2A but is based only on ecosystems that have lost more than 98 percent of their original area. The greatest losses are among grasslands, savannas and barrens. The ecosystems included in this chart are listed in Table 1.

* Noss, R.F., E.T. LaRoe III, and J.M. Scott. 1995

Figure 3.

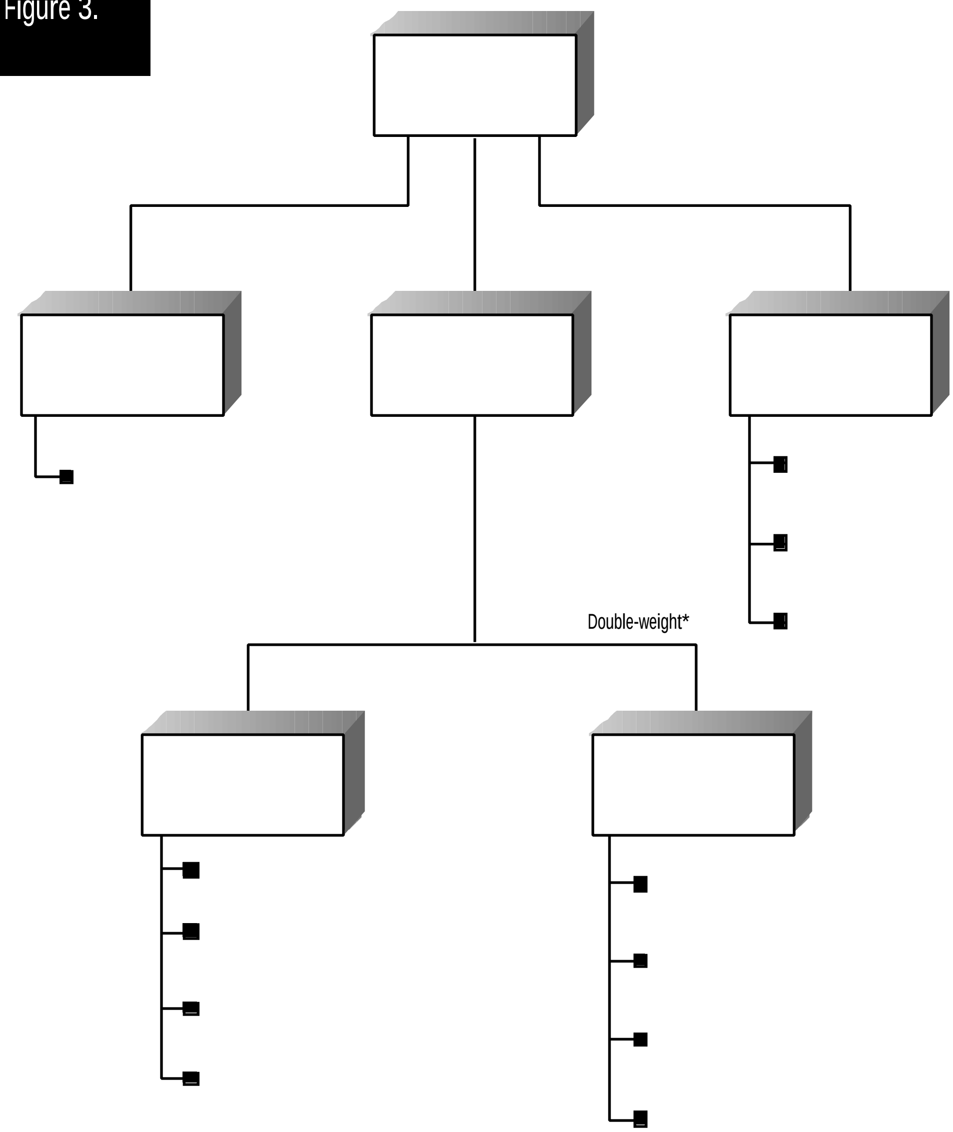


Diagram of Subindices used to calculate Overall Risk Index (ORI) values for each state

* Development Trend Subindex was given twice the weight of the Development Status Subindex and calculating DRI.