11

SAFEGUARDING OUR PRECIOUS HERITAGE

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Nestled amid the Appalachian Mountains of southwestern Virginia and northeastern Tennessee lies the Clinch Valley, the nation's leading hot spot for imperiled aquatic organisms. The Clinch River is the only undammed headwater of the Tennessee River basin, which in turn is the nation's most biologically diverse drainage system. The surface waters of the Clinch run rich indeed: They are home to at least 29 rare mussels and 19 rare fish. Underground, the region's limestone bedrock is honeycombed by more than a thousand caves and uncounted underground springs and streams. This little-known world is filled with a menagerie of rare beetles, isopods, and other subterranean insects. These underground realms have yielded more than 30 species new to science in just the past few years.

The Clinch Valley is largely rural and sparsely populated. Most residents make their living directly from the land, either mining coal, harvesting timber, grazing cattle, or planting crops. These rural lifestyles have maintained much of the region in a relatively natural state, and more than two-thirds of the Clinch Valley remains forested. The forested hills mask a history of ecologically unsound land use practices, however, that have degraded the legendary quality of the region's waterways. Virtually anything released in the valley flows downhill into the streams and rivers. Among the greatest threats to the valley's extraordinary aquatic life are heavy metals leaching from abandoned coal mines, sediment eroding from cutover slopes, and nutrients released by streamside-grazing cattle. These and other threats have already taken a toll on the region's extraordinary biological richness. Where once there were 60 kinds of freshwater mussels, only about 40 remain.

Coastal southern California, in contrast, is one of the most densely populated regions in the nation. It, too, is a hot spot for imperiled spe-

The Clinch Valley in southwestern Virginia and northeastern Tennessee is the nation's leading hot spot for imperiled aquatic organisms. © Jon Golden/TNC.

cies. Its dry Mediterranean climate and varied topography have favored the evolution of a host of unique plants and animals. Altogether, some 86 imperiled species are found along the coast and in the mountains of this nationally significant center of biodiversity. Certain areas stand out even by California standards as having a truly extraordinary diversity of rare species. The Otay Mountain area, near San Diego, for instance, lends its name to a host of locally restricted species, including the Otay Mesa mint (*Pogogyne nudiuscula*), Otay manzanita (*Arctostaphylos otayensis*), Otay tarweed (*Hemizonia conjugens*), and Otay Mountain lotus (*Lotus crassifolius* var. *otayensis*).

Coastal southern California differs dramatically from the Appalachian valley of the Clinch River. One is among the poorest regions in the country, the other one of the wealthiest. While traditional land uses in the Clinch revolve around extracting a living from the land, the high-tech economy of southern California depends almost entirely on imports of raw materials—particularly water. Fertile fields once planted to oranges, avocados, and strawberries now sprout housing developments. But while the flat agricultural lands are some of the easiest to develop, the scenic hills overlooking the Pacific Ocean are among the most desirable. An acre of prime oceanview land can be worth as much as $4 million. Unfortunately, even as increasing numbers of people are seeking homes here, these hills are also the last refuge for a number of increasingly rare or imperiled species.

Coastal sage scrub, an austere yet aromatic mixture of shrubs, is one habitat that has been particularly devastated by southern California's human population explosion. Once it blanketed millions of acres in the southern part of the state, but now coastal sage scrub is found on only about 400,000 acres. The demise of these shrublands has precipitated a decline in those species that rely on them for their survival, most famously the California gnatcatcher (*Polioptila californica*). Federal listing of this diminutive bird as a threatened species provided a catalyst for developers, conservationists, and government officials to tackle the region's toughest conservation issue: how to allocate scarce lands needed for the survival of wildlife in the face of relentless development pressures.

Conservation must ultimately take place at specific sites and be carried out by local communities. Each place represents a unique mix of ecological and human values, and effective conservation efforts must take both into account (Weeks 1997). What works in rural southwestern Virginia may be entirely inappropriate for the urbanizing hills of coastal California, and vice versa. On the other hand, while conservation action typically occurs at the local level, biodiversity conservation is not just a local enterprise. It is precisely because conservation has regional, national, and even global dimensions that this book takes a broad view of the status of biodiversity across the United States. Only with such a perspective can we effectively and efficiently set priorities for local action that support larger-scale conservation goals.

The Clinch River once supported 60 kinds of freshwater mussels, but pollution and sedimentation have taken a heavy toll: only about 40 mussel species remain. © Jon Golden/TNC.

This book has mostly focused on the past and the present. This chapter is about the future. What will be the state of the nation's wildlife as we approach the next millennium, a thousand years from now? What does the preceding assessment of the current status of species and ecosystems suggest about solving the biodiversity conservation crisis in a way that will allow us to reach that distant future with a landscape that is still biologically and ecologically intact? Can we envision a solution that, while recognizing the primacy of local action, is national in scope? If so, what is the scale of that solution? This chapter attempts to address those questions based on what we have learned through the preceding chapters and from the American conservation experience to date. The approaches we suggest, like conservation itself, are not science, but judgments based on science. They are not an experimentally verified surefire formula for the conservation of biodiversity, for there is no such formula. Rather, they represent a weaving together of what we have learned, what we know, and what we suspect into an approach to safeguarding the rich biological diversity of the United States.

Federal listing of the California gnatcatcher, which depends on coastal sage scrub, provided a catalyst for a regional effort designed to allocate scarce lands for biodiversity conservation.
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Reprise: State of the Nation's Biodiversity

The Appalachian Mountains and coastal California are but two of the nation's ecological treasures. As *Precious Heritage* documents, from a biological perspective the United States is an extraordinary place even on a global scale. Spanning a wide array of ecosystem types, from arctic tundra to tropical forest to blistering hot desert, the nation supports an enormous diversity of plant, animal, and microbial species. Although precise species counts are impossible given how little scientists still know about many groups of organisms, more than 200,000 species have been formally documented from the United States. And among those plants and animals about which we do have good information, several are better represented in the United States than in any other nation on Earth. No other country equals the United States in its diversity of salamanders, freshwater mussels, or freshwater turtles, for instance, and our freshwater fishes and coniferous trees are also impressive on a global scale. The United States is also particularly well endowed with such globally significant large-scale ecosystems as temperate broadleaf forests and prairies, and it harbors one of only five examples worldwide of Mediterranean-climate vegetation. The flora and fauna of the Hawaiian Islands exhibit some of the highest levels of endemism of any region on Earth, adding considerably to the biological significance of the United States.

Many of our natural ecosystems, however, have been despoiled over the past few hundred years. Consequently, the species that depend on those ecosystems have declined. Although naturally rare species are particularly vulnerable to environmental disturbances, even species with seemingly inexhaustible populations—such as the passenger pigeon or Carolina parakeet—can succumb to human depredations and disturbance. Indeed, more than 500 native species already are extinct or missing. Overall, about a third of the U.S. species that we examined in detail are of conservation concern and can be regarded as having an elevated risk of extinction. The levels of risk vary considerably for different

A sea of red-tiled roofs is rapidly overtaking southern California's remaining coastal sage scrub and related natural habitats, driving an array of species in this biological hot spot closer to extinction.
© C. C. Lockwood/Earth Scenes.

More than 200,000 species inhabit the United States; of these species, our freshwater organisms are especially impressive on a global scale. Aquatic species, such as this shasta crayfish (*Pacifastacus fortis*), are in particular peril. © B. Moose Peterson/WRP.

More than 500 U.S. species are already extinct or missing, including the colorful Carolina parakeet. The huge flocks of these parakeets were shot out of the skies by the late 1800s, although the last individual did not die until 1914. © The Academy of Natural Sciences, Philadelphia/Corbis.

groups of organisms, however. While such conspicuous groups as birds and mammals appear to be doing relatively well, those animals dependent on freshwater habitats are especially vulnerable. Almost three-quarters of freshwater mussels—a group for which the United States is a world leader—are vulnerable, imperiled, or already extinct, and the figures for other aquatic organisms, such as amphibians, fishes, and crayfishes, are also alarmingly high. Plants, which make up a considerable amount of the diversity of terrestrial habitats, also exhibit high levels of rarity and risk: About one-third are of conservation concern.

The natural ecosystems on which these species depend have been disturbed by human activities across the country. Outright habitat conversion for the production of food, fuel, and fiber and the construction of housing and other infrastructure has consumed vast areas. Our assessment of remaining natural vegetation, based on coarse-resolution satellite imagery, suggests that only about two-fifths of the conterminous United States remains in natural cover. Even this is likely an overestimate of intact natural habitat.

Other forms of ecosystem degradation are more subtle than the replacement of a forest with a shopping mall or a prairie with a wheat field. Disruption of natural fire regimes has transformed or diminished many ecological communities, such as the longleaf pine forests that formerly covered much of the southeastern coastal plain. Similarly, the extensive replumbing of the nation's waterways to generate power, supply drinking water and irrigation, and provide flood control has disrupted natural flow regimes, profoundly altering the functioning and composition of the nation's aquatic ecosystems. The spread of alien species is also wreaking havoc in both terrestrial and aquatic systems and is now the second leading threat to biodiversity, trailing only habitat destruction. The ecological and economic impacts of these invasive foreign species are escalating rapidly, and preventing additional introductions and controlling existing invasions will be a major challenge to society over the coming decades.

The nation's biodiversity is, of course, not uniformly distributed. Regions differ both in their biological richness and in the levels of current and potential future threats. In general, states with the highest levels of species diversity occur along the southern edge of the United States, from California across to Florida. Looking at the geography of risk—that is, the proportion of a state's flora and fauna considered vulnerable or imperiled—many of these same states stand out. Hawaii, however, towers above all other states in the level of risk to its native biota. Because Hawaii's magnificent flora and fauna evolved in isolation, its species are unusually susceptible to human perturbations. Sadly, more extinctions have occurred on this small island chain than anywhere else in the United States.

Most rare species are localized or, if distributed more broadly, are restricted to few populations or occur at low densities. Even where they occur, they often are difficult to find and easy to overlook. The rarest of the rare, however, are precisely the species that are most susceptible both to human activities and to natural perturbations. Unless specifically targeted for protection, these are the most likely to fall through our conservation safety nets. To incorporate them into conservation efforts, though, we must have a sound understanding of their ecological requirements and geographic distribution. We can now broadly decipher the geography of imperilment, thanks to the wealth of detailed data gathered on the distribution of imperiled species over the past quarter century by state natural heritage programs. Building on the work of field biologists from universities, natural history museums, botanical gardens, and other governmental agencies, this detailed population-level heritage information presents a powerful picture of species imperilment across America.

Habitat destruction is the leading threat to the nation's biodiversity, and only about two-fifths of the nation retains its natural vegetation. © Gary Braasch

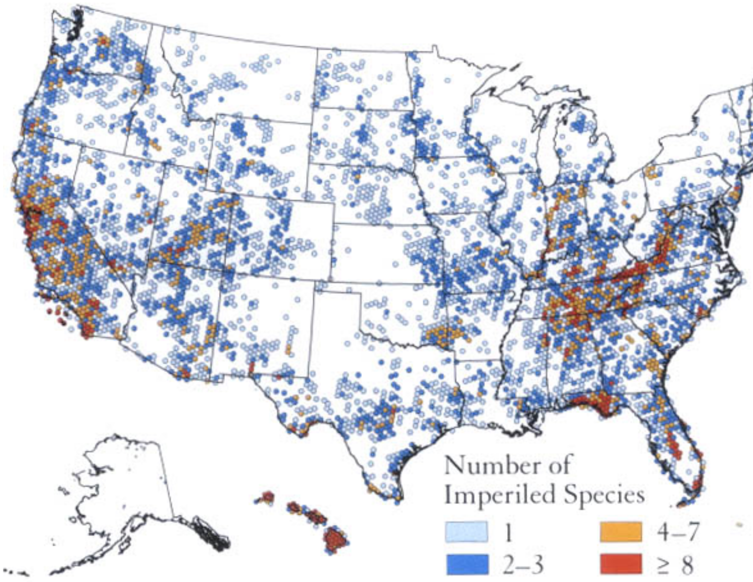
Certain regions harbor exceptional concentrations of imperiled species, a product of their ecological attributes, geological history, and the scale of human alteration to the landscape. Hot spots of rarity and richness for imperiled species occur in such places as the Hawaiian Islands, the southern Appalachians, central and southern California, the Death Valley region, and the Florida Panhandle (figure 11.1). The flip side of this tendency for rare and imperiled species to be concentrated in some areas is that many regions have few or no such species. In analyzing the known distribution of nearly 2,800 imperiled species (chapter 6), we found that more than two-thirds of the United States lacked any imperiled species. Indeed, fully one-third of these species are not known to occur in more than one of the 160,000-acre sampling grids used in that analysis.

Although over time the nation's portfolio of protected areas has incorporated many national treasures, biodiversity typically has not been a primary factor determining which lands are protected by public agencies. As a result, our protected lands do a far better job of preserving scenic landscapes than they do of safeguarding imperiled species and unique ecosystems. We are a nation with many rock and ice parks but with relatively few that—like Ash Meadows National Wildlife Refuge and its complement of rare desert fishes, snails, and plants—focus on protecting the less glamorous but in many ways most needy of our biological inheritance. Only a small percentage of the nation's imperiled and federally listed species populations are located on lands that afford the highest levels of biodiversity protection. Based on our analyses of species distributions and land ownership patterns (chapter 10), lands that provide the best protection, such as national parks, wilderness areas, wildlife refuges, or private nature preserves, safeguard fewer than one-tenth of imperiled species populations. Most populations of imperiled species occur either on multiple-use lands or on lands subject to intensive uses that offer little or no legal protection.

Even as efforts can be made to improve the degree to which biodiversity is safeguarded on the public estate, the importance of private lands to protecting our imperiled species and ecosystems is becoming increasingly evident. For example, among species legally protected under the federal Endangered Species Act, we found that about two-fifths are not known to occur anywhere on federal lands, so protection of these species must occur on nonfederal lands—state, tribal, and private. Yet the tools that we have in hand to encourage the conservation of biodiversity on private lands still

Figure 11.1. Hot spots for imperiled species.

While certain regions harbor exceptional concentrations of imperiled species, many others have few or no such species; more than two-thirds of the United States lacks any known imperiled species. Biodiversity conservation efforts will need to account for this uneven distribution of imperiled species across the landscape.



rely primarily on regulation rather than on providing incentives for the maintenance of functional ecosystems and healthy species populations.

Comparing the location of biodiversity hot spots (figure 11.1) with the density of human population (figure 11.2) makes it clear that conservation in the future increasingly will require balancing human needs and aspirations with the ecological requirements of these species and the ecosystems on which they depend. How will we succeed in doing so? And with finite resources—biological, financial, and human—what is success likely to look like?

What Successful Conservation Means

Biodiversity is a vastly complex resource, difficult to atomize into freestanding units whose worth or value can be assessed independently. Considerable ink has been spilled arguing whether or not any individual species is inherently worth saving, either because it is essential to ecosystem integrity or because it is indispensable to human existence. The Endangered Species Act is itself a formal testament to American society's concern that the variety of living things is something worth sustaining. Given that commitment, and the foregoing assessment of the perilous condition of much of our biodiversity heritage, is a solution possible? If so, what will it take to achieve that solution?

We have already seen that significant numbers of species and natural communities are at elevated risk of extinction and that most of these are in that condition owing to habitat destruction or alteration. Habitat loss and alteration are themselves fueled by the growing demands of human society, the changing ways in which we choose to use our lands and waters, and by alien species, which generally are introduced deliberately or

Figure 11.2. Night lights of the United States.

Comparing the location of biodiversity hot spots (figure 11.1) with the density of human population, as revealed by the nighttime satellite view of the United States, makes it clear that future conservation will involve balancing human needs and the ecological requirements of the species and the ecosystems on which we depend. Source: National Oceanic and Atmospheric Administration.

accidentally by humans. For many species, population size and/or number depend on the amount of habitat available. The more habitat there is, the more or larger populations there are. A well-known principle of conservation biology is that the chances of extinction for a species depend, at least in part, on population size and number (Soulé 1987). The smaller or fewer populations a species has, the greater the likelihood the species can become extinct simply by chance alone. As the human population grows and more and more land area is converted from natural habitat to human uses, populations of those wild species that depend on natural habitats will necessarily become fewer and smaller.

The biodiversity crisis is, in essence, about room. Many species and communities are simply running out of the room they need to survive. And with them will go the incredible wealth of the species' genetic information and the ecological connections that represent the wiring for functional, sustainable ecosystems. Arresting this downward spiral and successfully conserving biodiversity means leaving room in the national landscape for some of everything—all native species and all natural communities—and enough room for each to last. Successful biodiversity conservation comes down to this: *Save some of everything, save enough to last.*

This simple admonition belies the complexity of determining the adequate representation of species and communities throughout their historical ranges, or the difficulties of determining the spatial requirements for long-term survival. Nevertheless, some simple principles can help inform conservation efforts. These principles can be termed *representation*, *resiliency*, and *redundancy*.

Some of Everything: Representation

Noah's ark is a common, but too simple, metaphor for biodiversity conservation. Biodiversity is composed of species, the genes they contain, the communities and ecosystems they form, and the processes that connect them. Consequently, successful biodiversity conservation means saving more than the species themselves. It means saving the ecological and evolutionary patterns and processes that not only maintain but also generate those entities we call species. Because every species' genetic makeup is shaped, through natural selection, by the environments it has experienced, successful conservation also means saving populations of each species in the array of different environments in which it occurs.

Take pumas (*Felis concolor*) as an example. Their historical distribution stretched from Canada to Tierra del Fuego—the widest natural distribution of any mammal in the Western Hemisphere, with the exception of humans. Across this broad range they inhabited a variety of environments from temperate to tropical, interacting with, and helping shape, many different species, from mule deer (*Odocoileus hemionus*) in the coniferous forests of the Rocky Mountains to guanaco (*Lama guanicoe*) in the mountain grasslands of the southern Andes. We can "save the puma" by maintaining them only in Canada and letting them disappear elsewhere. But this will not fully accomplish biodiversity conservation. For that, we need healthy populations of pumas in most or all of their environments. So do the mule deer and guanaco.

Similarly, on a broad scale, some ecological systems occupy vast areas of the United States. Just as a species' genetic composition can change from one environment to another, so assemblages of species within a coarsely defined ecological system can vary from one place to another along an environmental gradient. An example is the tallgrass prairie ecoregion discussed in chapter 7. Although named for its most prominent vegetation feature, this region actually encompasses numerous ecological communities, including oak woodlands and floodplain forests in addition to many discrete grassland types. Many of these communities are restricted to the Great Plains and play important ecological roles in the overall system. Clearly, protecting only "tallgrass prairie" remnants will not result in truly representative conservation of this ecoregion's diversity. Nor will preserving tiny fragments of prairie encompass the large-scale ecological processes that are so important in maintaining these systems. Again, we will be challenged to recognize our conservation targets in a way that captures the full spectrum of such natural variation across the landscape, and on a geographic scale that can truly encompass this ecological diversity and its attendant processes. The principle of representation—saving some of everything—will require identifying conservation targets not simply as species and communities but as the complexes of populations, communities, and environmental settings that are the true weave of biodiversity.

Mountain lions inhabit a wide range of habitats, from Canada to Tierra del Fuego. Successfully conserving this cat will require that populations be maintained through all or much of that environmental range. © Tom and Pat Leeson/Photo Researchers.

Enough to Last: Resiliency and Redundancy

In August 1998, a driver transporting chemicals used for manufacturing Styrofoam took a wrong turn. En route from Georgia to Connecticut, the driver somehow left the highways that are approved for the transport of his hazardous materials and ended up navigating the winding roads of the Clinch Valley. Driving too quickly around one sharp turn, the tanker tipped on its side, discharging about 1,250 gallons of highly toxic liquid into the Clinch River. The Clinch ran a snowy white color, shutting down the water filtration plant at Richlands, Virginia, and killing off most aquatic organisms along a seven-mile stretch of river (Hylton 1998). Unfortunately, this reach of the Clinch harbored three federally listed freshwater mussels, including one of the only two populations on Earth for the tan riffleshell (*Epioblasma florentina walkeri*). That tan riffleshell population was completely destroyed, wiping out half the world's supply of this mussel in one freak accident. The only other population of this critically imperiled mussel, located in a nearby creek, was narrowly spared the lethal effects of the toxic effluent. Although this single population of the tan riffleshell still survives, the organism is now even closer to the brink of extinction. Literally, all of its eggs are in a single watery basket.

A toxic spill in August 1998 killed most aquatic organisms along a seven-mile stretch of the Clinch River (*above,* © Jon Golden/TNC), including one of only two populations of the tan riffleshell mussel (*below*, © Richard Biggins/ USFWS).

Complex machines, such as jet airplanes or spacecraft, are engineered with backups for their critical systems so that failure of a single component will not lead to catastrophic failure. These system redundancies provide the margin of safety needed to make such things as flight and space travel safe for humans. So, too, biological systems need *redundancy* in the engineering sense of having essential backups in place to guard against complete system failure. And just as each component in a jet or spacecraft is engineered to be as resilient to failure as possible, *resiliency* is also essential for the long-term survival of a species.

The issue of viability is key to understanding how resiliency and redundancy inform the scope and scale of a solution to the biodiversity problem. Viability, in the conservation context, is a simple concept to understand but difficult to quantify or predict. A species or its component populations are viable if they continue to exist. They are not viable if they go extinct. A variety of factors can determine the outcome: long-term climate change, arrival of a new competitor or predator, evolution of a new parasite or disease, or a misread map.

Virtually any factor that can bring a species to extinction can operate in one of two different ways, either as a systematic pressure or as a random perturbation. Take climate, for example. A long-term, rangewide shift in climate may make the environment so unsuitable for a particular species that its reproduction does not keep pace with mortality and the overall population size begins to decline. If that species fails to adapt to the change through natural selection, it will eventually become extinct no matter how large its populations are or how many it has. Such a long-term climate shift can be thought of as a systematic pressure on the species.

On the other hand, even in times of stable climate, no two years are exactly alike. There is almost always annual variation in temperature and rainfall. These annual variations, if severe or prolonged, may also cause a species to decline. Whether or not the species survives depends on the balance between its initial population size, the degree to which the random environmental factors depress population growth, and the duration of the unfavorable conditions. A large population of long-lived individuals might be able to endure a 5- to 10-year drought, but a small population might not. This type of year-to-year random variation in weather, in the absence of any long-term directional change in climate, is an example of a random perturbation.

Clearly, any species subjected to a continuing, systematic pressure sufficient to produce a population decline is not viable. If that pressure cannot be relieved, the species will become extinct. On the other hand, a species with a population growth rate that, on average, is positive, may or may not be viable. Its long-term survival depends on the number and size of its populations in relation to the types and amounts of random perturbations they are likely to experience.

The relationship between habitat area and a species' population size and persistence has been demonstrated for an array of species on a variety of scales (Meffe and Carroll 1997). For example, Newmark (1995) documented a strong negative relationship between the size of 14 western North American national parks and the number of local mammal extinctions from those parks in the years since their establishment. Similarly, the importance of multiple populations for a species' persistence has been demonstrated for such disparate organisms as checkerspot butterflies (*Euphydryas editha*, Murphy 1990) and Furbish lousewort (*Pedicularis furbushiae*, Menges 1990).

Determining the viability of a species or its populations is a challenging task. For the vast majority of species, including most of those in need of conservation, we lack the level of detailed knowledge necessary to quantify how viability will respond to changes in population size and number. We do know that, all else being equal, the chances of maintaining a species at a site will increase as the size of the site increases. Further, we know that, all else being equal, the chances of maintaining a species overall will increase as the number of sites at which it is maintained increases. We can think of the size of sites as a measure of *resiliency*, and the number of sites as a measure of *redundancy*.

Saving enough to last will require designing conservation sites that are large enough to support populations of the target species and that are resilient to the types of random perturbations inherent in the natural world. As the tan riffleshell mussel reminds us, no single population is immune to the chance of catastrophic extinction—from causes as diverse as hurricanes and toxic spills. Saving enough to last will therefore also require protecting enough sites to provide the backup redundancy necessary as a hedge against the failure of any individual population.

The Emerging Scale of Habitat Need

Conservation in America historically has focused on a narrow range within the full spectrum of biodiversity. Early efforts in wildlife management and natural area conservation targeted either particularly charismatic species, or outstanding examples of natural features. Regulating hunting and fishing were important initial steps in the conservation movement but affected relatively few species. Our first protected areas, such as Yellowstone and Yosemite, were designated as much for, and delimited as much by, their geological features as by an understanding of their ecological value.

Even our most ambitious biodiversity conservation law, the Endangered Species Act, takes an incremental, species-by-species approach to conservation. A species must be judged to be in danger of extinction throughout all or a significant portion of its range, or of becoming in danger of such extinction, to qualify for protection efforts. Even then, the efforts to protect such species are often narrowly focused on that species without broader consideration of the natural system of which it is part. The net result has been a steady accumulation of species listed as endangered or threatened, a proliferation of species-specific recovery plans, and a growing backlog of unmet demand for conservation action.

The recent proliferation of multispecies habitat conservation plans, in which natural groupings of species are treated together, is a step in the right direction in many cases. Even habitat conservation plans, however, hinge on some species' becoming so rare as to qualify as threatened or endangered. This often means waiting until few options remain for successful conservation, either because there are too few populations left or because the ones left are too small to be resilient. There is no indication that continued reliance on this approach, alone, will halt the accelerating erosion of biodiversity. Putting an end to the ever growing list of endangered and threatened species, and the growing backlog of unmet conservation needs, will require new, more comprehensive approaches to the problem.

One alternative approach would be to use the kind of information presented in this book, along with the principles discussed above, to design a system of lands and waters capable of protecting the full range of biodiversity. Such a national portfolio would encompass multiple (*redundant*), *resilient* populations and natural communities that *represent* the full range of environmental and ecological settings in which those species and communities normally occur. If such a system of lands and waters could be identified and then managed to maintain the elements of biodiversity they currently support, we might have a comprehensive solution to the biodiversity conservation issue, at least for that part due to habitat loss.

Are such designs possible? If so, what would they look like? How big would they be? What issues and challenges do they raise for the conservation community and our broader society?

What might a national portfolio of protected lands look like that encompasses the concepts of redundancy, resiliency, and representation? © Frank Oberle.

Encompassing Imperiled Species

In chapter 6 we considered how much land area would be required to encompass each of nearly 2,800 imperiled species in the United States. Based on detailed species population data from each U.S. natural heritage program, we mapped the known distribution of these imperiled species using a uniform grid in which each hexagonal cell covers about 160,000 acres. Because many imperiled species are concentrated in certain regions, we found that protecting habitat in cells covering just 6% of the United States could capture at least one example of each imperiled species. Even this is probably an overestimate of the total land area required, since these cells are statistical units rather than naturally defined areas, and imperiled species typically are restricted in their distribution even within these general areas.

This 6% solution may meet the simplest representation goal by covering each species at least once, but what about the redundancy in coverage necessary to improve the species' chances for survival and guard against catastrophic extinction of any single population? Although multiple populations of a given species may occur within a single hexagon, let's assume that each cell encompasses but a single population of any species. Our ability to provide replication is limited by the distributions of the organisms themselves: Only two-thirds are found in two or more hexagons, just a quarter are found in five hexagons or more, and a mere 13% of these species are distributed in as many as eight (figure 6.12). Extending double coverage to those species that occur in two or more hexagons increases the land area needed to 10%. Further extending coverage to include up to eight hexagons per species increases this figure to about 20% of the land area.

Admittedly, this analysis provides only a crude initial estimate of the scale of habitat need for imperiled species. We know that the inventory effort on which the analysis is based is still incomplete. Furthermore, this includes only imperiled species, which are the rarest of the rare and geographically among the most restricted plants and animals. This analysis also doesn't take into account many other declining or threatened species, some of which are wide-ranging and require habitat that extends well beyond a single hexagon. Nonetheless, it offers one of the first quantitative efforts to address the emerging scale of habitat need by looking at the issues of representation and redundancy at a national level.

Ensuring Viability: Closing the Gaps in Florida

At least one major effort to design a comprehensive habitat system for protecting biodiversity has gone beyond representation and taken into account the principles of resilience and redundancy. In 1994, the Florida Game and Freshwater Fish Commission published a report entitled *Closing the Gaps in Florida's Wildlife Habitat Conservation System* (Cox et al. 1994). This pioneering work sought to determine what set of lands in the state would, if kept in their current condition, provide adequate habitat for the state's declining wildlife species and rare plant and animal communities. Although the plan was not able to address the specific needs of all the thousands of species found in Florida, it employed a well-reasoned list of focal species selected either for their value in indicating the presence of specific habitats and natural communities or because, like the Florida panther, the species needed large amounts of habitat.

The plan also set out explicit criteria for evaluating viability. Adequate conservation, under this plan, was defined as providing enough habitat for at least 10 populations of at least 200 individuals for each focal species. Distributed correctly, such multiple, large populations could address the principles of redundancy, resiliency, and representation. The planning effort also took the sensible approach of first determining whether the viability criteria for each focal species could be met on existing conservation lands, most of which are already in public ownership.

At the time of the study, existing conservation areas covered just under 7 million acres, or about a fifth of the state (shown in blue on figure 11.3). These lands were sufficient in size to meet the conservation needs of 14 of the 44 focal species; that is, the above viability criteria for these species could be satisfied somewhere on existing public and private conservation lands. Meeting the needs of the remaining species would require conservation of additional lands. The report identified another 4.8 million acres of mostly private lands, which the authors designated as Strategic Habitat Conservation Areas (shown as red on figure 11.3). These additional lands represent about an eighth of the state. If the report's recommendations were implemented fully, approximately one-third of the land area in Florida would fall into some type of conservation land use.

The results of this study contain good news and bad. First, the good news. The fact that such a planning effort was possible is itself remarkable. The study bears witness to our growing level of knowledge of the distribution and status of many of the elements of biodiversity, made possible, in part, by the network of state natural heritage programs—the Florida Natural Areas Inventory, in this case—and to our growing understanding of the factors that affect the long-term viability of populations and species. Second, to the extent that the design principles employed prove to be functional, a comprehensive solution to the biodiversity habitat conservation problem appears to be possible. Third, implementing that solution will not affect most of the land in the state.

Now the bad news. Although this solution to the habitat conservation issue in Florida would not affect most of the land in the state, it does involve a large amount of land, a good portion of which is privately owned. The estimated purchase price for the privately held Strategic Habitat Conservation Areas identified in the plan was $5.7 billion at 1994 market prices. To place this figure in context, consider that through its Preservation 2000 Program—probably the most ambitious state habitat ac-

The Florida plan for creating a habitat conservation system considered the viability requirements of a carefully selected set of focal species, like this gopher tortoise (*Gopherus polyphemus*) (*top*, © Stephen Krasemann/DRK PHOTO), and the degree to which existing conservation areas, such as Big Cypress National Preserve (*bottom*, © Carr Clifton/Minden Pictures), could satisfy these needs.

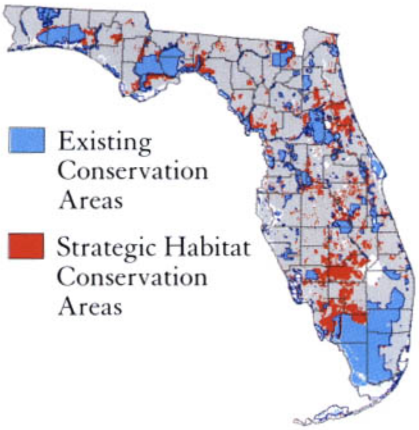


Figure 11.3. Closing the gaps in Florida.

This map shows those habitat areas in Florida that should be conserved if key components of the state's biological diversity are to be maintained. Existing conservation areas are shown in blue, while additional lands needed are indicated in red. Together, these account for about one-third of the state. Source: Cox et al. 1994.

quisition effort in the nation—the state of Florida has spent $3.2 billion during the 1990s to acquire important natural areas. During this same period the federal government's expenditure to acquire habitat and natural areas nationwide was only about $250 million annually, a figure less than what this one state alone is spending. On the other hand, the January 1998 proposed annual budget for the state of Florida amounted to $45 billion, and a single B-2 stealth bomber costs $2 billion.

A Geography of Hope: Designing Ecoregional Portfolios

The Nature Conservancy's effort to design portfolios of conservation sites within each of the nation's ecoregions (see figure 1.1) represents a similarly comprehensive approach for assessing the scale of habitat needs. Now a cornerstone of the Conservancy's efforts, ecoregion-based conservation grew out of the organization's realization that successfully conserving ecological communities and imperiled species will require working on increasingly broader scales and across state boundaries (TNC 1996). This approach also recognizes the inherent conservation value of the biodiversity contained within each ecoregion, and not just in areas that stand out as imperiled species hot spots. Although the Conservancy is designing these portfolios on the scale of ecoregions, the collective portfolio, when completed, will represent a truly national conservation blueprint.

Chapter 10 discusses one of the first such ecoregional planning effort, focusing on the interior Northwest's Columbia Plateau. Plans are complete or under way in numerous other regions, ranging from the Central Shortgrass Prairie and the Northern Appalachians to the East Gulf Coastal Plain. Within each of these ecoregions, the objective is to identify portfolios of conservation sites that together could provide for the long-term survival of each of the region's viable native species and natural communities. Although each ecoregion is unique, planners are using a consistent process to set planning goals (TNC 1997). Conservation targets typically include vulnerable species and communities—including species that may still be abundant but are of special concern due to declines or other factors—and the full range of ecological communities, both common and rare. Identifying a wide spectrum of conservation targets allows planning teams to address the principle of representation discussed earlier. Explicit conservation goals for each target focus on the number of populations or occurrences that would be needed to maintain the viability of these species and communities. Together, these conservation targets and goals incorporate the concepts of representation, resiliency, and redundancy into the process. The resulting portfolio of conservation sites would represent a "geography of hope" (TNC 1997).

The Pawnee Buttes in the western high plains of northern Colorado are included in one of the conservation sites identified in the Central Shortgrass Prairie ecoregional plan. © Harold E. Malde.

While many of these ecoregional planning efforts are still under way, we already are learning some important lessons about the scale of land conservation that will be necessary to achieve these ambitious conservation goals. In the Central Shortgrass Prairie—a sparsely populated ecoregion that occurs mostly in Colorado but extends into Kansas, Nebraska, New Mexico, Texas, and Wyoming—the planning team analyzed the protection needs of about 200 species and natural communities (TNC 1998a). These researchers identified a set of proposed conservation sites that encompass just under a quarter (22.5%) of the region's area (figure 11.4). Of these portfolio lands, 15% are already in public ownership. If managed for the protection of their biodiversity, this portfolio of sites would protect about two-thirds of the species and communities identified as conservation targets. Only about a quarter of the targets, however, are represented in these sites in numbers sufficient to achieve the viability goals the planners set for themselves, an indication that the opportunity to build fully resilient conservation systems with adequate redundancy is fast slipping away.

Most other completed ecoregional plans call for the conservation of similar ratios of land, ranging from about 15% to 25% of the ecoregion's area. The Columbia Plateau plan, for instance, identified a portfolio of sites encompassing 21% of the region. Although about 60% of these portfolio lands are in public ownership, even here private lands will play a critical role in meeting biodiversity conservation goals.

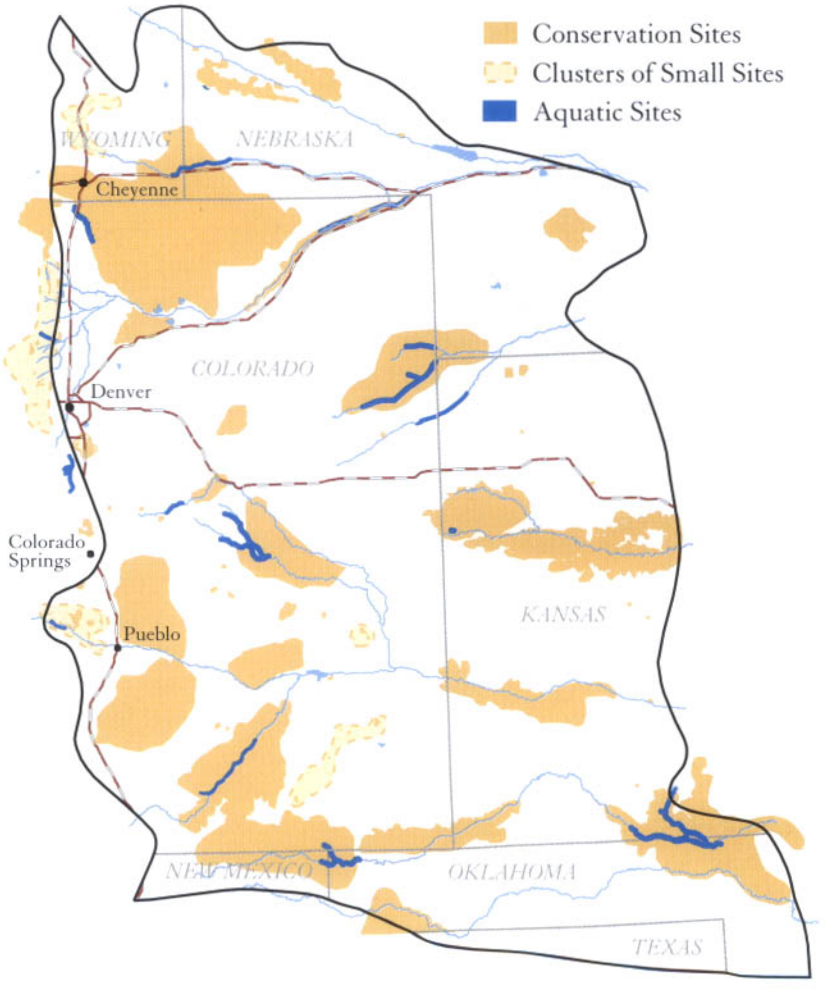


Figure 11.4. A conservation portfolio for the Central Shortgrass Prairie ecoregion.

Conservation planners have identified a set of proposed conservation sites that encompass just under a quarter of the region's area. If managed for conservation, this portfolio of sites would protect about two-thirds of the region's key species and communities. Source: TNC 1998a.

Standing in sharp contrast is the highly fragmented landscape of the Northern Tallgrass Prairie, an ecoregion spanning North and South Dakota, Minnesota, Iowa, and Manitoba. During the ice ages, glacial Lake Agassiz covered much of this region, leaving behind the flat terrain of the Red River Valley and the surrounding gentle rolling plains. This area has been subjected to intensive agricultural conversion, and at present only about 4% of the region remains in any form of natural vegetation. Because of the relatively few areas remaining in natural habitat, the conservation portfolio identified for this ecoregion encompasses only 3% of the land area, almost all of which is located in just a handful of large-scale landscapes. The Northern Tallgrass Prairie provides a dramatic illustration of how our existing options for biodiversity conservation can be severely constrained. It also points to the role that restoration may need to play as part of the long-term strategies for conserving and restoring biodiversity in highly altered regions.

Community Conservation in California

Like the Northern Tallgrass Prairie, southern California is another area where biodiversity conservation choices have already been severely constrained, in this case primarily by rampant urbanization. This hot spot of imperiled species is the location of another regional planning approach to allocating scarce land for conservation.

Known as the Natural Community Conservation Planning (NCCP) program, a broad coalition of conservationists, government agencies, and the business community have come together to try and determine what will be needed over the long haul to preserve the unique ecological communities and species that inhabit this rugged yet populous region. Each of these parties has a powerful incentive to work toward an overall solution to the problem. As natural habitats have declined, so too have the species dependent on them, leading to increasing numbers of endangered species listings by the federal and state governments. Although listing of the California gnatcatcher as threatened was just one such decision, its reliance on coastal sage scrub affected development and land use decisions throughout the region, creating political pressure to resolve the issue. Developers were frustrated by time-consuming delays and the uncertainty of outcome—the by-product of regulating on a species-by-species and parcel-by-parcel basis. The conservation community, for its part, recognized that the largely uncoordinated process of environmental review and development meant that regionally habitat would continue to be lost, as would any hope of creating meaningful and long-lasting conservation areas out of the region's remaining natural habitat.

In 1991, the state of California created the NCCP as a way of developing conservation strategies and guidelines for the entire region in an atmosphere of collaboration rather than confrontation. The process was designed to avoid the type of bitter and costly environmental battles then raging in the Pacific Northwest over the listing of the spotted owl. A scientific panel worked to create a vision for establishing a reserve network that could protect the full array of ecosystems in the region. While the coastal sage scrub would be a focal community, the plan would extend to all other natural communities as well. Basic principles included keeping blocks of habitat contiguous, linking habitat preserves through corridors where possible, and buffering habitat from encroaching development (CDFG 1993).

In central Orange County a plan has now been approved that sets aside more than 37,000 acres for preservation. Meanwhile, the City of San Diego to the south has approved plans for a 164,000-acre preserve system. While the Orange County plan mostly involves public lands and relatively few large landowners, the San Diego effort encompasses numerous smaller land parcels and landowners. The eventual purchase of about 27,000 acres of private lands for the San Diego preserve system is estimated to cost between $300 million and $400 million. Although science has strongly informed the preserve selection process, the NCCP necessarily operates within the political environment as well, and the process has made important strides in bringing together previously warring factions. Whether these lands will be sufficient to safeguard the region's declining wildlife over the long term is still a matter of scientific debate. Nonetheless, these preserves offer some hope for the host of imperiled species that were steadily losing ground to a sea of red-tile-roof housing developments.

As part of California's Natural Community Conservation Planning effort, Orange County has approved a plan that sets aside more than 37,000 acres for preservation of the region's dwindling wildlife resources. © Harold E. Malde.

Beyond Acquisition

The message from these regional planning efforts—from Florida's attempt to close its gaps to The Nature Conservancy's effort to create ecoregional conservation blueprints—makes one thing abundantly clear. Approaching biodiversity conservation through land acquisition alone would be an extremely costly venture, probably in the range of hundreds of billions of dollars. This represents an undertaking akin to building the Interstate Highway System or similar major public works program. But as the authors of the Florida report point out, the real issue is not acquisition but management. Much of the land identified in their Strategic Habitat Conservation Areas is in low-intensity land uses, such as forestry or rangeland. These lands, if maintained and appropriately managed, could sustain the elements of biodiversity that are still present. In this sense, the conservation challenge is not to change the ownership of these lands but to find positive incentives to encourage current and future owners to maintain conservation-compatible land uses.

As a nation we are accumulating a substantial management debt that no amount of land acquisition will solve. Certain threats to our native biodiversity—the spread of alien species, disruption of natural fire regimes, or alteration of hydrological flows—can so transform affected ecological systems as to render them unsuitable for sustaining native species. Paying off this management debt will increasingly be the focus of conservation efforts. Indeed, in the future conservation will be less about preserving pristine settings—these are already few and far between—and more about improved management of seminatural lands and restoring degraded landscapes.

Land that could be managed in a conservation-compatible manner make up a surprisingly large amount of the nation's landscape. Just over half (55%) the land in the United States is thought to be in seminatural condition, that is, neither intensively used nor carefully preserved (Weeks 1997). In contrast, probably only about 3% of the landscape is strictly protected as parks or nature preserves (Noss and Cooperrider 1994). Clearly, these seminatural lands will take on considerable importance if we are to achieve the levels of land protection—one-sixth to one-quarter of the landscape—indicated by the various studies discussed earlier. Biodiversity conservation in the future will increasingly rely on such seminatural lands, not only as buffers around and corridors among protected areas, but also as biodiversity reservoirs in their own right.

Our accumulating management debt applies equally to public lands and private, although as a society we are in a better position to address the problem on the public estate. Fortunately, many government agencies are beginning to recognize the problem and take steps to manage their lands with an eye toward preserving the natural biodiversity values. The Department of Defense, for instance, is an unlikely ally in the fight to protect our natural heritage. As our chapter 10 analyses demonstrate, with bases located in a number of biologically significant regions, relative to their surface area defense lands are inhabited by a disproportionately large number of endangered and imperiled species. The various branches of the armed services generally have taken seriously their role and responsibility to maintain these species. Some installations, such as Eglin Air Force Base in the heart of northern Florida's imperiled species hot spot, have been especially vigorous in managing their lands in a way that maintains biodiversity (Leslie et al. 1996)

Improved management of public lands, however, is unlikely to be sufficient by itself, given what we know about the frequency with which imperiled species occur on private lands and the effect that management of private lands can have on such public resources as rivers and streams. We urgently need incentive-based approaches to working with private landowners. In the Clinch Valley, for example, conservationists are experimenting with a variety of techniques to encourage landowners to employ land management practices that will benefit the region's extraordinary aquatic biota. These incentives focus on reducing the sediments and other contaminants from their lands due to incompatible land use practices. Farmers are being encouraged, and receiving financial incentives, to fence off sensitive riparian areas from grazing cattle. In 1998 conservationists began establishing an innovative forest bank for the valley that would allow landholders to enroll forested acreage and receive a long-term financial benefit from the harvest of timber, yet have the forest bank as a whole managed according to ecologically sound forestry principles.

Truly turning around the problem of protecting endangered species on private lands will require a fundamental shift in how they are perceived by private landowners. Endangered species are now often perceived by landowners as a net liability, something that may interfere with economic uses of the property. What is needed are incentives that can turn the presence of these species into an economic asset. Although locally based incentive programs, such as those under way in the Clinch, are encouraging, a national-level commitment to providing incentives for the protection of endangered species and biodiversity habitat on private lands will be essential.

Into the New Millennium

Much of this chapter has focused on issues of scale, especially the geographic scale needed for habitat protection. Entering the new millennium, however, compels us to consider scale of a different sort: time. Thousand-year increments—millennia—represent virtually an eternity in human time. Yet we are now confronted by choices that will reverberate not only for decades but for centuries and, indeed, millennia. These choices will largely determine what wild species will survive into a third millennium, and what the condition of the earth's ecological support systems will be. Given that humans themselves depend on the natural services provided by functioning ecosystems, these choices will also be crucial for human well-being and existence.

While a thousand years may seem a long time from a human perspective, this still is too short a period to consider. On a geological and evolutionary timescale, a thousand years is barely perceptible. The origin and evolution of life in what is now the United States has ancient roots, as reviewed in chapter 3. The uplift of the Appalachian Mountains, for instance, began almost 300 million years ago, and amphibians had emerged from the early seas at least 60 million years earlier. Continental plates have shifted positions through the ages, but North America essentially took up its current position by about 14 million years ago.

The history of life on Earth has been one of increasing diversity and complexity. This largely has been a result of two competing forces operating over the vastness of evolutionary time: *speciation*, the evolution of new species, and *extinction*, the demise or transformation of previously existing species. The diversification of life on Earth has not been without interruptions; five mass extinction events have occurred, the most drastic about 250 million years ago, marking the end of the Permian period. The most recent, and famous, is the mass extinction that happened some 65 million years ago at the end of the Cretaceous period, apparently as a result of an asteroid smashing into the earth in the vicinity of the present-day Yucatan Peninsula. After each of these extinction events the earth has rebounded in diversity, although accompanied by major shifts in the constellation of living organisms. The Cretaceous extinction, for instance, brought the age of dinosaurs to a close and ushered in the age of mammals, leading ultimately to humans. Humans, in turn, are responsible for the current surge in extinctions, which many biologists consider the beginning of a sixth period of mass extinctions.

Given the earth's track record for rebounding from the previous five extinction events, and the fact that extinction is a "natural" process, why should we be overly concerned with the biological losses confronting us now? This brings us back to the issue of temporal scale. In the evolutionary interplay between extinction and speciation, we have greatly accelerated the extinction side of the equation. Extinctions can now be measured in the very human span of years and decades (see Appendix A). Any counterbalancing evolution, however, will tend not to occur on a timescale relevant to human existence. Instead, emergence of new species typically occurs over tens of thousands or millions of years. Furthermore, the very activities pushing so many species toward extinction in the first place are also impoverishing the genetic reservoirs that ordinarily might serve as the raw materials for future evolution.

But though the asteroid that is headed toward us this time is, figuratively speaking, of our own making, we also have the power to avoid it. To have a chance for success, though, the conservation choreography will have to occur on the very human timescale of the next few decades. Doing so will also require knowledge and commitment to action.

Knowledge will be key to tackling this monumental task: What species and ecosystems exist, where they are found, what is their condition, and what are their needs? *Precious Heritage* is a celebration of one effort—the Natural Heritage Network—to gather and make accessible just this sort of knowledge to inform and improve land use and conservation decisions. Meeting the massive conservation challenges ahead of us, however, will require that we substantially increase our basic knowledge about the natural world, both what exists and how it functions. This task must necessarily involve the entire research and inventory infrastructure—universities, museums, agencies, and individuals—that contributes to the ongoing discovery of life in America.

Yet knowledge is just the first step and must be transformed into action. This conservation action must take place before our options have evaporated and been converted to strip malls, housing developments, and wood chips. The Clinch Valley offers an example of a biologically diverse region which presents significant conservation challenges but in which numerous options are still available. Coastal southern California provides a stark illustration of the high costs—biological and financial—once conservation options are severely constrained.

As we learn more about how natural ecosystems work, we are drawn inevitably to thinking on broader scales, both geographically and temporally. To be successful, though, we must take that grand vision and translate it into action at particular places inhabited by real people. Ultimately all conservation is local. The long-term success of biodiversity conservation efforts will hinge on local communities' embracing the need for healthy ecosystems and flourishing wildlife populations. It will also depend on an enlightened economics that has learned to value not just individual species but the very fabric of biodiversity.

Safeguarding the nation's precious natural heritage will be a central challenge as we enter the new millennium. © Jim Brandenburg/Minden Pictures.

One of the great contributions of the Natural Heritage Network has been its ability to link local biodiversity concerns with national and global priorities. That attribute challenges us to think on these broader scales even as we ground our conservation actions in particular ecosystems and local communities. As the new millennium dawns, we are greeted by a set of choices that will be critical for the future of life in America, not just into the next decades but into yet another millennium. Many of these choices may be difficult—scientifically, politically, socially, or financially. Solving the biodiversity crisis and protecting the nation's extraordinary biological heritage will force us to reach beyond today's efforts, but is an imperative that we cannot let slip through our grasp.

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