Noss & Cooperrider 1994 Saving Nature's Legacy

by Noss (1992c). The theoretical and em-
of design will be considered in detail in
he proposed network are vague and need to
inventories and more detailed mapping.
osed in this study range in size from 1554 to
(40,371 acres). The total area covered by
6,483 ha (1.25 million acres), or 23 percent of
region. The total area covered by proposed
imated with precision, but is approximately
he Coast Range. Thus, the two reserve cate-
out 50 percent of the Coast Range. Multiple-
dditional 25 percent. These figures contrast
3 percent of the Coast Range currently pro-
natural areas, and other reserves (Noss 1992c,
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we will explore some biological and ecological
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hy large, interconnected reserve systems are

CHAPTER FIVE

DESIGNING RESERVE NETWORKS

> Wilderness complements and completes civilization. I might say that the existence of wilderness is also a compliment to civilization. Any society that feels itself too poor to afford the preservation of wilderness is not worthy of the name of civilization.
>
> Edward Abbey (1982), *Down the River*

In Chapter 4, we explored some criteria, databases, and techniques for recognizing areas of high conservation value. We emphasized selection of biodiversity hot spots (centers of endemism, rarity, or high species richness) and sites needed to assure adequate representation of all ecosystems and species in reserves. We also noted that it is a good idea to protect roadless areas and other wildlands, even or perhaps especially when we know little about their biological value.

Identifying hot spots, other important sites, and gaps in their representation in reserves is only the first step toward protecting these areas. Now we must design a system of reserves or a land-use regime that will maintain the dynamic biodiversity of these areas and the entire region in which they exist in perpetuity. No one knows precisely how to do this. But we can assess what has been learned from 100 years of trial and error in land conservation and piece together a strategy that has a high probability of success.

Sometimes the process of identifying hot spots leads directly to some kind of reserve proposal, without much more effort in design. For example, a serpentine or limestone ridge full of endemic species is an instant candidate for a reserve, and its boundaries are naturally defined. As another case, if we are interested in protecting old-growth forests, a map showing the location of remaining stands can be used to determine the location of large,

relatively unfragmented stands that are of highest value for conservation, a process followed in the Oregon Coast Range project described in Chapter 4.

Although the general locations of reserves show up immediately in many conservation evaluations, defining reserve boundaries usually requires additional work. For instance, we may need to consider buffer zones to shield sensitive sites from external influences. We should estimate the sizes of populations that might inhabit a site and the ability of animals or plant propagules to travel between sites. We should assess the area of habitat needed to support viable populations or metapopulations. If we are using Gap Analysis data, we must examine in greater detail the broad areas recognized as important on a statewide scale to see how species and vegetation types are distributed on the landscape and where feasible reserve boundaries and linkages might be located.

Usually, the process of finding important sites (Chapter 4) addresses only the first of our four major conservation goals: representing all native ecosystems across their natural range of variation. To maintain viable populations and ecological and evolutionary processes and implement a land-use regime that will allow organisms to adapt to changing environments, we must consider issues of reserve size, proximity, connectivity, other aspects of pattern, and perhaps above all, how to manage the overall landscape. These issues are often more difficult and politically contentious than simply distinguishing areas of conservation value.

Nature Reserves or Multiple Use?

A controversy has been fermenting among managers and biologists about how best to conserve biodiversity. The debate is most intense concerning federal lands (Grumbine 1990a, Brussard 1991). Two major approaches have been proposed: (1) establish more or bigger parks, wilderness areas, and other reserves; or (2) manage better the semi-natural matrix (multiple-use public and private lands) that covers most of our country (Brown 1988).

These two options are not mutually exclusive. Most conservation biologists will probably agree that in most regions we should pursue both options in tandem. We need more and bigger reserves *and* more ecologically sensitive management of other lands. Biologists differ greatly in the emphasis they give to each option but not over the need for both. Nature reserves—defined here as areas managed primarily for their natural values—are central to land-use planning because they are the places that have the most to lose if not managed properly. They are also benchmark areas with which lands exploited by humans can be compared. If selected, as they

should be, to represent hot spots of biodiversity and other critical sites, nature reserves are by definition irreplaceable or very nearly so.

Potentially destructive development or management practices should not be allowed in nature reserves. Sites outside reserves and of lesser conservation value can afford greater management experimentation, such as with innovative forestry techniques designed to provide commodities for people as well as to maintain most elements of biodiversity. Because land-use experiments may succeed or fail, reserves must be able to sustain species unlikely to persist in multiple-use areas. Uncertainty about the long-term impacts of management practices on biodiversity is reason enough to be conservative and place as much area as possible in wilderness or other strictly protected reserves. These reserves then can function as benchmarks for management experiments. As noted by Aldo Leopold (1941), wilderness provides a "base-datum of normality" for a "science of land health." It is an imperfect baseline because human impacts often cross boundaries and all natural communities change over time, but it is the best we have. Scientists shudder to think of experiments without controls, but this is what happens with much of our land management (Noss 1991b).

We do not believe that resource management is inherently destructive, but so far the record of its effects on biodiversity is rather bleak. Some new techniques are promising, but it is too early to say that they are safe. We can predict that many native species will persist on multiple-use lands with current practices, at least in the short term. But protecting many species is not good enough. We must strive to maintain *all* native species. Unless we slow the extinction rate to natural levels (sometimes estimated as about one species lost globally each year, balanced by slightly more than one new species created per year) we remain "Man the exterminator" (Diamond 1982).

Reserve Design in the United States: A Brief History

Soulé (1987) felt that most of conservation history has been concerned with the "protection of whole systems." In contrast, Simberloff (1991) stated that "[u]ntil the advent of the 'new conservation biology' . . . , refuges were usually chosen on the basis of habitat. The key was extensive knowledge about the autecology of species of interest, especially their habitat requirements, followed by a search for the most substantial amount of that habitat one could find." We disagree with both of these assessments. Until recently, science—whether "whole system" science or autecology—rarely entered into the conservation process.

A glance at our present reserve system in the United States shows little influence of science in selection or design. Many national parks are essentially square. Few conform to watersheds, mountain ranges, or other physiographic or biogeographic features that define natural regions. Most parks are too small to maintain viable populations of the largest animals that inhabit them (Newmark 1985, 1987). The lack of attention to science is reflected in the enabling legislation for our major reserves. As noted in Chapter 1, the national parks were created to conserve scenery and other natural objects, and secondarily to provide for public enjoyment of these things. Wilderness areas were established to preserve areas "where the earth and its community of life are untrammeled by man" (in Zaslowsky 1986), with little attention to ecological or scientific criteria (Nash 1984). Although the Wilderness Act of 1964 includes scientific value among many potential reasons for designation, scientific value is not mandatory or preeminent (Davis 1988). Virtually all agency assessments of wilderness proposals in recent years have focused on expected recreational visitor days (Noss 1990b).

National wildlife refuges were established on grounds that are ostensibly more scientific. The refuges were set aside to "provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity and location to meet society's needs for areas where the widest spectrum of benefits associated with wildlife and wildlands is enhanced and made available" (National Wildlife Refuge System Act of 1966, cited in Zaslowsky 1986). The four main purposes of the refuges were to protect habitat of endangered species, to perpetuate migratory bird populations, to preserve natural diversity of all animals and migratory birds, and to engender an understanding and appreciation of wildlife (Zaslowsky 1986). However, the design and management of refuges have fallen far short of these lofty goals (Defenders of Wildlife 1992, Norris 1992, Curtin 1993). The independent commission appointed by Defenders of Wildlife concluded that refuge system planning is weak, lacks a scientific basis, and rarely coordinates with threats and opportunities arising from management of adjacent lands (Norris 1992).

Other kinds of protected areas suffer from similar problems. Research natural areas, established on federal lands primarily to represent natural communities and to serve as baselines for comparison with manipulated sites, are far too small to serve this purpose adequately (Noss 1990b and see below). They are also affected by clearcutting and other incompatible activities on adjacent lands.

Incongruous Boundaries

The incongruity between natural boundaries and reserve boundaries has led to major problems for reserve managers. Everglades National Park was one of the first and only national parks set aside to protect an ecosystem rather than mainly to protect scenery. Yet this 1.4 million acre park, bounded by the 586,000 acre Big Cypress National Preserve and 862,000 more acres in three water conservation areas (Fig. 5.1), is failing in its mission. The symptoms of degradation are many. In the 1870s wading birds, including 16 species of herons, bitterns, ibises, spoonbills, and the endangered wood stork, had combined populations as great as 2.5 million birds (Robertson 1965). Today, populations have been reduced by perhaps 90 percent and the nesting population in the national park is an ever smaller fraction of the regional total. Breeding pairs of wood storks have declined steadily in south Florida since the 1960s (Ogden *et al.* 1987). Exotic trees like Brazilian pepper and melaleuca now dominate much of the Everglades and have led to changes in hydrology, fire regimes, and biota.

What went wrong in the Everglades? The simple answer is that the park and adjacent conservation lands are not big enough to encompass the functional ecosystem that sustains the Everglades. The park was treated as a self-contained unit and expected to take care of itself with little effort from

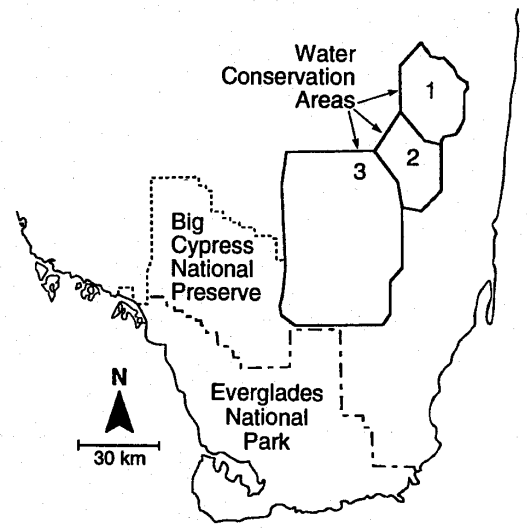


FIGURE 5.1 Southern Florida, showing major contiguous reserves in the Everglades ecosystem.

managers and little attention to what happened beyond its boundaries. Yet, the Everglades ecosystem actually encompasses most of south Florida. The hydrological regime of the Everglades begins naturally in the chain of lakes just south of Orlando, some 200 miles north of the Park. Canals, levees, and withdrawals and deliveries of water for agriculture and cities (the timing of which does not coincide with natural seasonal cycles) have altered the Everglades ecosystem beyond the ability of many native species to adapt.

The underlying problem in the Everglades, as with most other reserves throughout the United States, is the failure to take a regional perspective and coordinate efforts among a multitude of agencies and landowners (Kushlan 1979, 1983; Harris 1990). At least ten state and federal agencies have management jurisdiction over the Everglades ecosystem (Harris 1990). To perform naturally, the Everglades cannot be partitioned by artificial boundaries and multiple mandates. Rather, millions of acres—from Orlando to Florida Bay and from the Gulf of Mexico to the Atlantic Ocean—must be managed as a functional ecosystem. Although creating a park that encompasses most of South Florida is not politically feasible today, ecological management must indeed span this vast area. To this end, Harris (1990) has suggested the creation of a regional biosphere reserve. Although the park is already designated a biosphere reserve, the functional ecosystem was not included in the boundaries.

A second example of incongruous boundaries is provided by Yellowstone National Park, the oldest, largest, and most famous of all our parks. At 2.2 million acres, Yellowstone might be expected to be fairly secure. Yet, it is a grossly incomplete sample of the 14 to 19 million acres that constitute the Greater Yellowstone Ecosystem (GYE; Fig. 5.2). The GYE is rightly considered a showcase of American wilderness. Its values are summarized nicely by Glick *et al.* (1991): "What is significant about Greater Yellowstone's biological diversity is not the sheer numbers of species, and not even the abundance of many of the species that are present, but the fact that Greater Yellowstone's natural diversity of species is still essentially intact." Yet the famous biodiversity and wildness of Yellowstone are at risk. The park is much too small to maintain viable populations of some key species, most notably the grizzly bear (Shaffer 1992). In fact, an area much larger than even the GYE is needed to maintain grizzly bears in the long term. The Park is also not large enough to exist in balance with its disturbance regime, as natural fires in the GYE are characteristically large and catastrophic (Romme and Knight 1982).

The size of the park would not be such an issue if the lands surrounding it were managed in an ecologically responsible manner. Some 28 state and federal agencies and committees share management responsibility for the

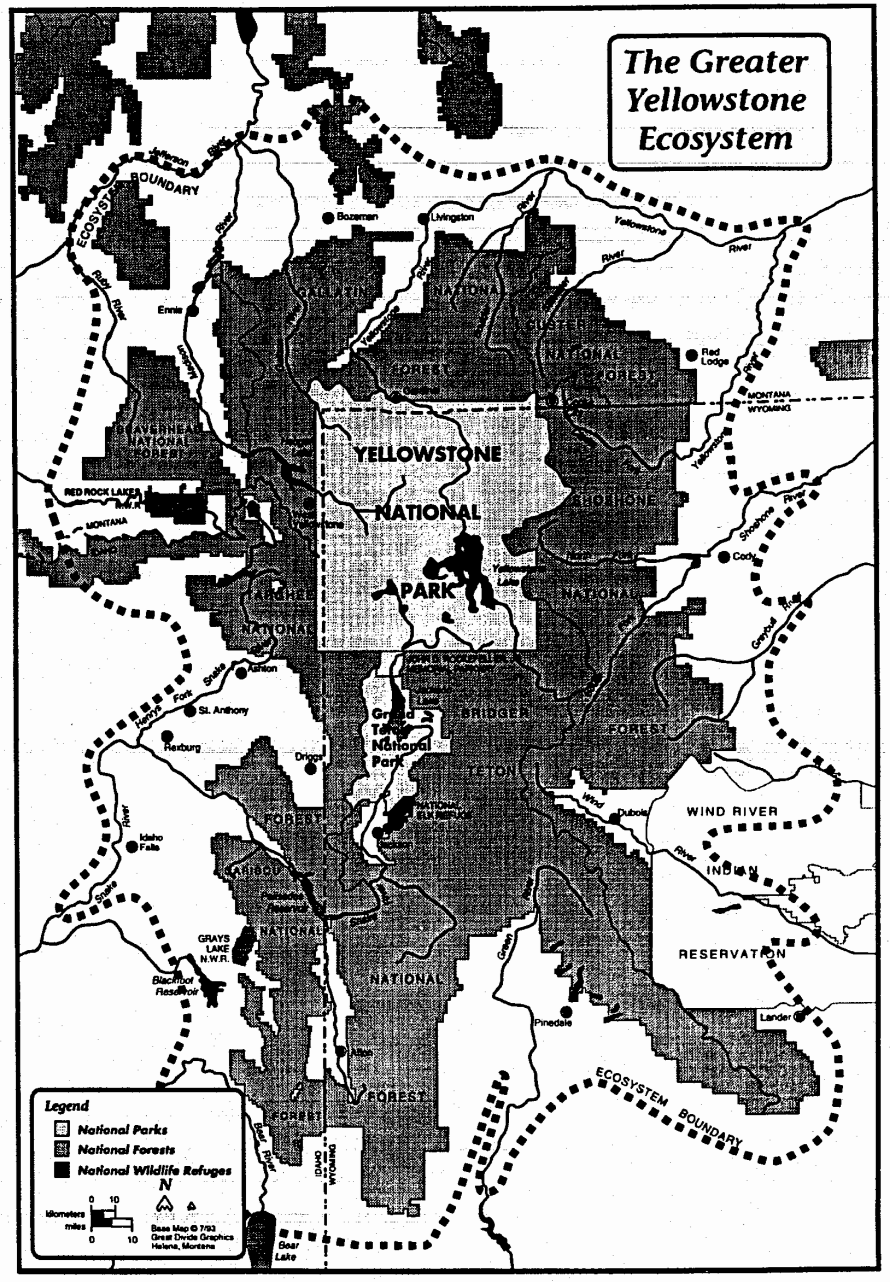


FIGURE 5.2 The Greater Yellowstone Ecosystem, variously defined as 14 to 19 million acres in size. From Great Divide Graphics, Helena, MT.

GYE, and each has a different idea about how the land should be managed (Goldstein 1992). Biodiversity conservation is not a major concern for many of these agencies. The U.S. Forest Service controls the largest area, about 60 percent of the GYE, but its lands are divided among three administrative regions and seven national forests. The most visible insult to the integrity of the park is heavy clearcutting on adjacent national forests, particularly the Targhee National Forest in Idaho (Fig. 5.3). More troubling than the visual impacts created by clearcutting next to park boundaries is what many consider to be the managerial hubris involved. Ironically, all seven national forests in the GYE run deficit timber programs, meaning it costs more to log than comes back to the government in revenue from the wood (Goldstein 1992).

Associated with clearcuts on national forests around Yellowstone are roads that provide access to other disruptive human activities, including poaching. Illegal shooting as well as killing of alleged "problem" bears by managers are the major sources of mortality for the grizzly bear in the GYE (Mattson 1990). Removal of roads and sheep allotments, where grizzly mortality is concentrated, is probably essential to grizzly recovery (Mattson and Reid 1991).

Livestock production, expecially of sheep and cattle, is perhaps the greatest threat to biodiversity in the GYE. Roughly 50 percent of the public lands in the GYE, including all three national wildlife refuges, BLM lands, portions of all seven national forests, and even Grand Teton National Park, are leased for livestock. The impacts of livestock production extend well beyond the direct effects of grazing on vegetation. Livestock production is largely responsible for the extirpation of the wolf and black-footed ferret in the GYE, the endangerment of the grizzly bear, declines in bighorn sheep, management conflicts with bison and elk, decline of native fishes due to dewatering of streams for irrigation and degradation of riparian zones, invasion of weedy plants, and soil erosion (Noss 1991e, Wuerthner 1992).

In addition to these problems, the GYE is threatened by subdivisions and development, virtually unrestricted tourism, mining, and oil and gas development (Glick *et al.* 1991). Each of these threats has the potential to escalate greatly in coming years.

How can we protect our premier national park? The solution is essentially the same as for the Everglades or any other park we might name: the entire regional landscape must be managed in a coordinated fashion toward the objective of biodiversity conservation. Agencies and citizens must work together, perhaps by establishing a lead agency with strong conservation credentials and overall management authority, to assure that activities incompatible with biodiversity conservation cease throughout the GYE. No

FIGURE 5.3 The boundary between Yellowstone National Park (left) and Targhee National Forest (right), illustrating lack of cooperation by the USDA Forest Service for managing its lands as a buffer zone for this biosphere reserve. Photo by George Wuerthner.

matter how difficult this objective may seem politically, the alternative—biotic impoverishment—is unacceptable.

Like the Everglades, Yellowstone has already been designated a biosphere reserve. But as with the Everglades, the boundaries of the biosphere reserve stop with the park and fail to encompass the greater ecosystem. Furthermore, as Figure 5.3 vividly attests, the park lacks a fundamental feature of a model biosphere reserve—buffer zones. The absence of buffer zones is due to lack of cooperation by the Forest Service and ultimately to lobbying from commodity interests (Keiter 1989, Goldstein 1992). An interagency effort to improve cooperation was quashed by political pressure (Milstein 1991). The Greater Yellowstone Ecosystem remains uncoordinated and unprotected.

These two examples of incongruous boundaries, simplified for brevity, show that biodiversity conservation will not succeed if constrained by political boundaries and the disparate mandates of multiple agencies (Grumbine 1990a, 1990b). Isolated parks will not work, nor will multiple-use management that degrades natural qualities. Identifying ecologically functional regions on the basis of physiography, hydrology, species distributions, population viability, migration routes, watersheds, vegetation patterns, fire regimes, patch dynamics, and other natural criteria is imperative. Then those regions must be managed to perpetuate ecological processes and biodiversity.

Island Biogeography and SLOSS

The biological basis for reserve design has strengthened as conservation science has evolved over the last two decades. The new conservation science of the 1970s was stimulated largely by the equilibrium theory of island biogeography, advanced a decade earlier by MacArthur and Wilson (1963, 1967; see Chapter 2). Recall that this theory considers species diversity on an island to represent a balance between immigration and extinction. Large islands that are close to a source of colonists are predicted to have the highest levels of diversity. Studies of land-bridge islands, isolated by rising sea levels after the Pleistocene, showed an apparent loss of bird species through time (Diamond 1972, Terborgh 1974). The analogy between land-bridge islands and terrestrial habitat patches isolated by development of the surrounding landscape was persuasive. Small isolated reserves, it was predicted, are doomed to lose species. Evidence began to accumulate that this prediction was correct.

Drawing largely from island biogeographic theory, Diamond (1975), Wilson and Willis (1975), and Diamond and May (1976) proposed rules for the design of nature reserves [Fig. 5.4; similar guidelines were suggested by Willis (1974) and Terborgh (1974)]. Later incorporated into the World

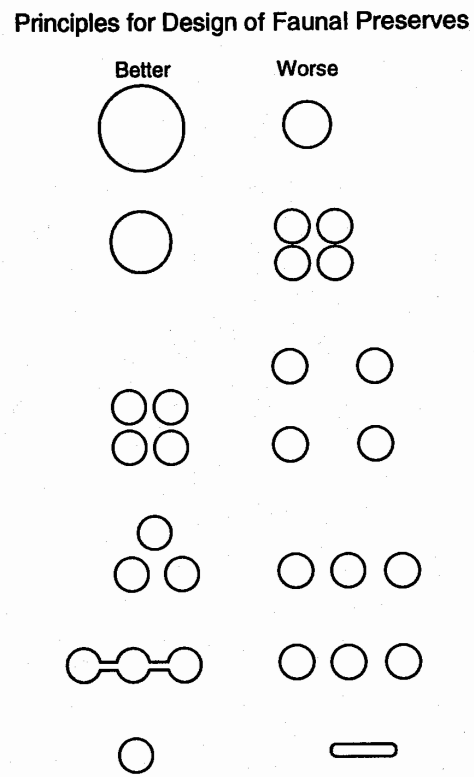


FIGURE 5.4 Principles for design of nature reserves, from Diamond (1975). In each comparison, the reserve design on the left is considered to be better for maintaining species diversity than the design on the right. Based in part on island biogeographic theory, these rules have been controversial. However, most have been validated by experience. Used with permission.

Conservation Strategy (IUCN 1980), the rules state that, all else being equal,

1. Large reserves are better than small reserves.
2. A single large reserve is better than a group of small ones of equivalent total area.
3. Reserves close together are better than reserves far apart.
4. Round reserves are better than long, thin ones.
5. Reserves clustered compactly are better than reserves in a line.
6. Reserves connected by corridors are better than unconnected reserves.

Immediately after these rules were proposed, other scientists challenged them as premature, given the lack of empirical data on island biogeography, problems with the equilibrium theory as proposed by MacArthur and Wilson, and dangers of extrapolating concepts from real islands to habitat islands (Simberloff and Abele 1976). These authors pointed out that in some situations several small reserves would be preferable to a single large reserve of the same total area because they would contain more species than the large reserve. The only criterion for what is better in these rules is the total number of species at equilibrium (Simberloff 1991). As we discussed in Chapter 4, species richness is only one of many important criteria for assessing the conservation values of alternative sites.

The six rules of reserve design appear to have been based as much on the collective field experience and biological intuition of those who proposed them as they were on island biogeographic theory. Following the rules might amount to "making the right decision for the wrong reasons" with regard to reserve design (Abele and Connor 1979). However, it is also possible that incorrect management decisions could be made if the mechanisms underlying the theory are incorrect (Simberloff 1991).

Rule #2 generated much more academic controversy than any other: the suggestion that a single large reserve is preferable to several smaller ones of equivalent total area. The literature on this debate, which came to be known by the acronym SLOSS (single large or several small), is perhaps larger than on any other topic in the history of applied ecology. The SLOSS debate was sometimes acrimonious and made for entertaining reading. It was not just coincidence that scientists arguing for small reserves mostly studied insects or plants, whereas those arguing for large reserves studied birds and mammals. Vertebrates, especially large-bodied species, are less likely than insects or plants to maintain viable populations in small areas. But besides giving academics lots of publications for tenure review and promotion, the SLOSS controversy accomplished little and was finally recognized as a red herring. When would decisions about selecting and designing reserves in the real world ever boil down to choices between single large or several small? In putting the SLOSS controversy to rest (although it still raises its ugly head from time to time), two biologists who had been on opposing sides of the controversy concluded that "bigness" and "multiplicity" are both essential criteria for establishing a system of reserves (Soulé and Simberloff 1986):

> Nature reserves should be as large as possible, and there should be many of them. The question then becomes how large and how many. There is no general answer. For many species, it is likely that there must be vast areas, while for others, smaller sites may suffice so long as they are stringently protected and, in most instances, managed. If there is a target species, then the key criterion is habitat suitability. Suitability requires intensive study, especially in taxa that contain species with narrow habitat requirements.

Today, few biologists would disagree that we need big reserves and lots of them. We expect that most would also agree that conservation decisions involve much more than just these two criteria, and that autecology (especially the life histories of species that are highly vulnerable to extinction or pivotal in the ecosystem) must assume a greater role in reserve design decisions (Soulé and Simberloff 1986; Simberloff 1988, 1991; Noss 1992b).

But where does this leave us? Do we need detailed studies of every species that might be sensitive to human activities before we make any recommendations about how to design reserve networks? We think not. In the absence of detailed autecological information, some empirical generalizations for reserve design stand out. In their conservation strategy for the northern spotted owl, Thomas *et al.* (1990) listed five reserve design concepts that they characterized as "widely accepted among specialists in the fields of ecology and conservation biology." We agree, and paraphrase these guidelines below, adding a sixth (from Noss 1992b) that applies to species that are especially sensitive to human disturbance and, therefore, greatly in need of protection.

1. Species well distributed across their native range are less susceptible to extinction than species confined to small portions of their range.
2. Large blocks of habitat containing large populations of a target species are superior to small blocks of habitat containing small populations.
3. Blocks of habitat close together are better than blocks far apart.
4. Habitat in contiguous blocks is better than fragmented habitat.
5. Interconnected blocks of habitat are better than isolated blocks, and dispersing individuals travel more easily through habitat resembling that preferred by the species in question.
6. Blocks of habitat that are roadless or otherwise inaccessible to humans are better than roaded and accessible habitat blocks.

Note that these guidelines are not all that different from those offered by Diamond and others 15 years earlier. They have proven to be extremely robust and are among the best-supported generalizations that conservation biology has to offer (Wilcove and Murphy 1991). The sixth guideline can

be shown to apply to most large carnivores, often the most sensitive species in an ecosystem, and also to the desert tortoise (U.S. Fish and Wildlife Service 1993) and other organisms likely to be exploited or persecuted by humans. Although these guidelines are oriented toward target species, they also apply to conservation planning at higher levels. But as we have hinted already and will explore in greater detail later, still other factors should be considered when designing reserve networks.

Biosphere Reserves

The old model of isolated parks has failed. Unless it contains many millions of acres, no reserve can maintain its biodiversity for long. Smaller parks are not only less likely to maintain viable populations, but they are also more heavily assaulted by activities beyond their boundaries. Scientists studying boundary problems around reserves (Schonewald-Cox and Bayless 1986, Buechner 1987, Dasmann 1988, Schonewald-Cox 1988) emphasize the importance of large areas and well-managed buffer zones. None of our national parks is big enough to maintain its diversity over time. Most are becoming more insular as surrounding habitats are modified by logging, grazing, suburban development, and other human activities. Smaller parks are losing species of mammals more rapidly than large ones (Newmark 1985, 1987).

A big step toward better integration of reserves and their surrounding landscapes was the development of the biosphere reserve model as part of UNESCO's "Man and the Biosphere" (MAB) program (UNESCO 1974). A main purpose of the program was to create a global network of protected areas for scientific research and monitoring and for protecting genetic diversity (Hough 1988). The MAB program stimulated development of a global classification system (Udvardy 1975) so that reserves could be selected to represent all of the earth's major biomes or biogeographical provinces.

Another impetus for biosphere reserves was the recognition that economic development ideally should lead to sustainable ways of life and that conservation will not succeed in the long run if it fails to consider the needs of local people (Dasmann 1988). This argument has been particularly cogent for the Third World. In some tropical countries, indigenous tribes that had lived sustainably with their landscape were displaced by new national parks, resulting in disintegration of their cultures and open hostility toward the parks (Dasmann 1988). This hostility was often expressed by vigorous poaching and other destructive activities. However, in the United States, it is not so much *people* who might be displaced by new reserve

designations on public lands, but rather certain kinds of human activities. When conducted as intensively as usual, clearcut logging, road building, livestock grazing, and mining are not sustainable ecologically. Off-road vehicle use is so blatantly harmful and frivolous that we wonder why there is even a debate about continuing this use on public lands. Eliminating destructive activities from public lands ultimately enhances both biodiversity and human well-being.

The zoning concept of biosphere reserves holds promise for integrating conservation and human activities. The basic biosphere reserve model (Fig. 5.5) portrays strictly protected core zones surrounded by one or more buffer and transitional zones and often containing areas for research, restoration, monitoring, and compatible human settlements. Unfortunately, this kind of zoning has seldom been implemented. By 1990 almost 280 biosphere reserves had been designated in more than 70 countries, including 43 in the United States (Dyer and Holland 1991). But most biosphere reserves have been superimposed on existing national parks and other protected areas without adding land. In 1983 only 1.6 percent of the

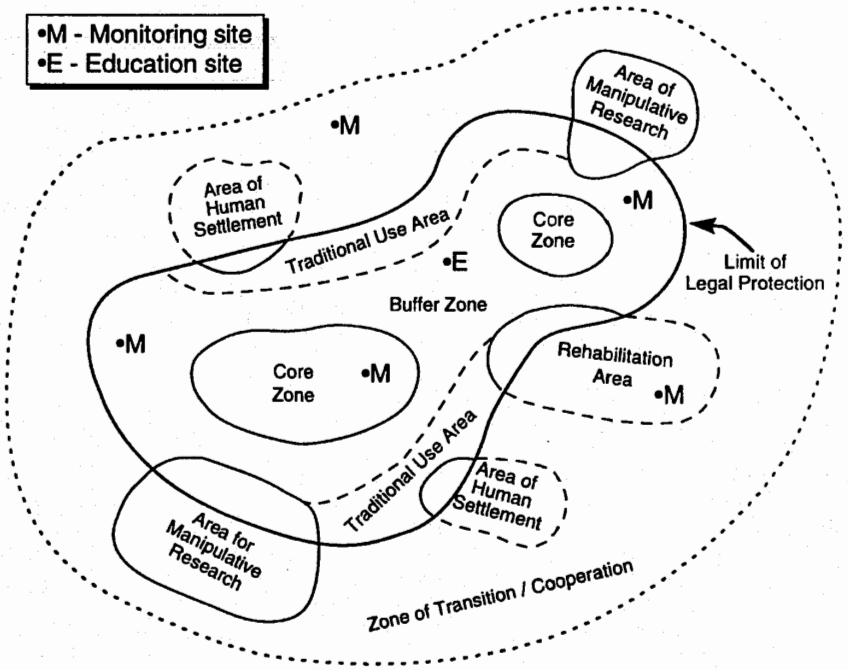


FIGURE 5.5 Conceptual layout of an ideal biosphere reserve (based on Hough 1988).

area in biosphere reserves worldwide was newly protected land, and by 1986 only 101 (52 percent) of 193 biogeographical provinces classified by Udvardy (1975) had been represented. Moreover, as noted above, biosphere reserves in the United States lack buffer zones. The biosphere reserve ideal remains unfulfilled.

Reserve Networks

A level beyond biosphere reserves is the concept of reserve networks. The basic idea is this: If functionally connected, a system of reserves may be united into a whole that is greater than the sum of its parts. Although no single reserve may be able to support a long-term viable population of a species with large area requirements, such as cougar or grizzly bear, reserves linked by corridors or other avenues of movement may do so (Noss and Harris 1986). Thus, whereas individual reserves are unlikely to encompass ecosystems replete with all native species, a well-connected network of reserves just might.

The reserve network concept was promoted by Noss (1983), Harris (1984), and others who looked at conservation opportunities from a landscape or regional perspective and emphasized the need for animals to move between reserves or other areas of favorable habitat. Landscape ecology developed in earnest in North America in the late 1970s and early 1980s (Forman 1981, Forman and Godron 1981) and was accompanied by studies showing that many animals use corridors when traveling through human-dominated landscapes (Wegner and Merriam 1979, Johnson and Adkisson 1985) and that corridors can enhance persistence of populations (Fahrig and Merriam 1985, Henderson *et al.* 1985). These studies, mostly carried out in agricultural landscapes, showed that population dynamics in individual woodlots are of only local importance. We must consider a network of woodlots to understand persistence of many species in these landscapes.

Noss (1983) described a "regional landscape approach to maintain diversity." He urged an expansion of conservation concern beyond local sites, emphasizing protection of old growth and other natural areas wherever they occur, a complex of large and small reserves, and broad corridors of natural habitat connecting reserves. He further suggested that effects of alternative designs and management strategies on diversity should be assessed regionally rather than site by site. Although a fragmented landscape may contain high species diversity, the species favored are mostly weedy and edge-adapted, whereas sensitive species decline. The net effect of these changes on regional biodiversity is negative. In line with this suggestion, an Australian study showed that, though a system of many small reserves maximizes species richness, those species found only in reserves are best served by a system of large reserves (Humphreys and Kitchener 1982). These findings reinforce the advice of Diamond (1976):

> [S]pecies must be weighted, not just counted; the question is not which refuge system contains more total species, but which contains more species that would be doomed to extinction in the absence of refuges. A refuge system that contained many species like starling and house rat while losing only a few species like ivory-billed woodpecker and timber wolf would be a disaster.

Harris (1984) presented a management strategy for old-growth forests in the western Cascades of Oregon in his landmark book, *The Fragmented Forest.* Harris' strategy was based on maintaining the characteristic regional fauna, rather than species richness per se, in line with Diamond's advice. He recommended the conservation of existing old growth, an integrated system of long rotation forest islands surrounded by replacement stands, and a dendritic network of corridors containing many nodes of small and medium-sized forest islands linking larger forest islands. He noted that his approach was designed to integrate conservation and development planning and "should be based on sound principles of multiple use, not preemptive policies of exclusive use. The archipelago approach shifts the emphasis away from any single old-growth habitat island toward a system of islands integrated into the managed forest landscape."

Harris (1984) also introduced the concept of the multiple-use module (MUM), essentially a generalization of the biosphere reserve model to a variety of spatial scales and management scenarios. The MUM concept was further elaborated by Noss and Harris (1986) and Noss (1987a). Its basic feature is a concentric design where intensity of use increases outward from the core and intensity of protection increases inward (Fig. 5.6). As applied to the Oregon Cascades, each old-growth island would be surrounded by a long-rotation buffer zone, thereby increasing effective island size, improving chances of forest persistence over time, and providing a spatial gradation from old growth into young managed forest (Harris 1984). More generally, it is essential that MUMs be located to capture nodes or hot spots of biodiversity and be linked by habitat corridors into a functional regional network (Fig. 5.7). Noss and Harris (1986) stressed that the MUM network strategy was consistent with agency mandates for multiple use because the system as a whole provides for many different uses. However, the most sensitive sites and species are insulated from disturbances arising in the landscape matrix.

In simplified form, then, the regional reserve network model consists of

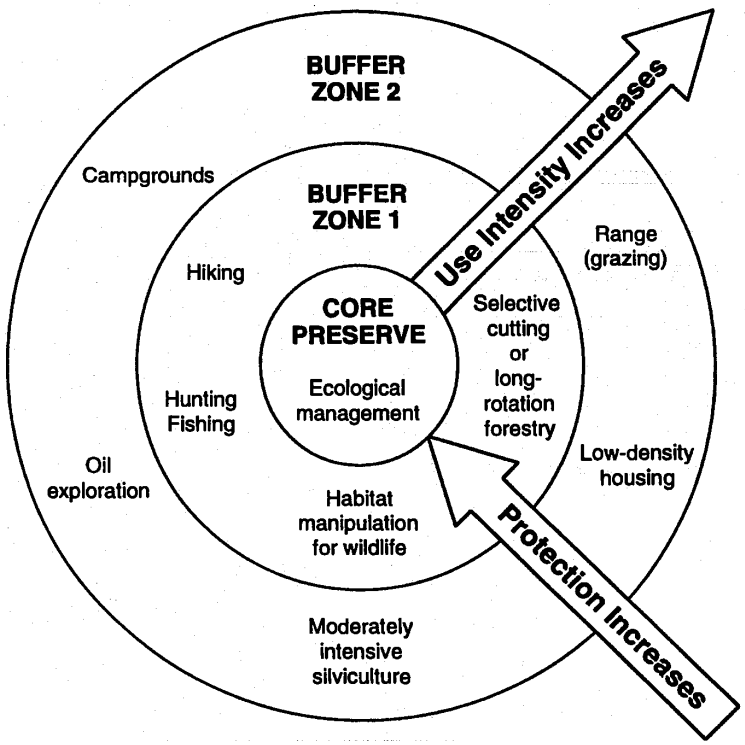


FIGURE 5.6 A multiple-use module (MUM). An inviolate core reserve is surrounded by a gradation of buffer zones, with intensity of human use increasing outward and intensity of protection increasing inward (from Noss 1987a, modified from Harris 1984). Used with permission of the Natural Areas Association.

two or more reserves connected by broad corridors, surrounded by a gradation of buffer zones, and connected to other regions (where biogeographically appropriate) by interregional corridors (Fig. 5.8). Thus, the strategy involves a combination of (1) more reserves, (2) bigger reserves, (3) interconnected reserves, and (4) more sensitive management of multiple-use lands. The strategy rejects resource tradeoffs and insists that we can have the best of all possible worlds if we put our minds to it and are willing to reduce our resource consumption and intensity of land use for the sake of the land. Below, we review some major features and functions of the three essential components of a regional reserve network: core reserves, multiple-use buffer zones, and connectivity.

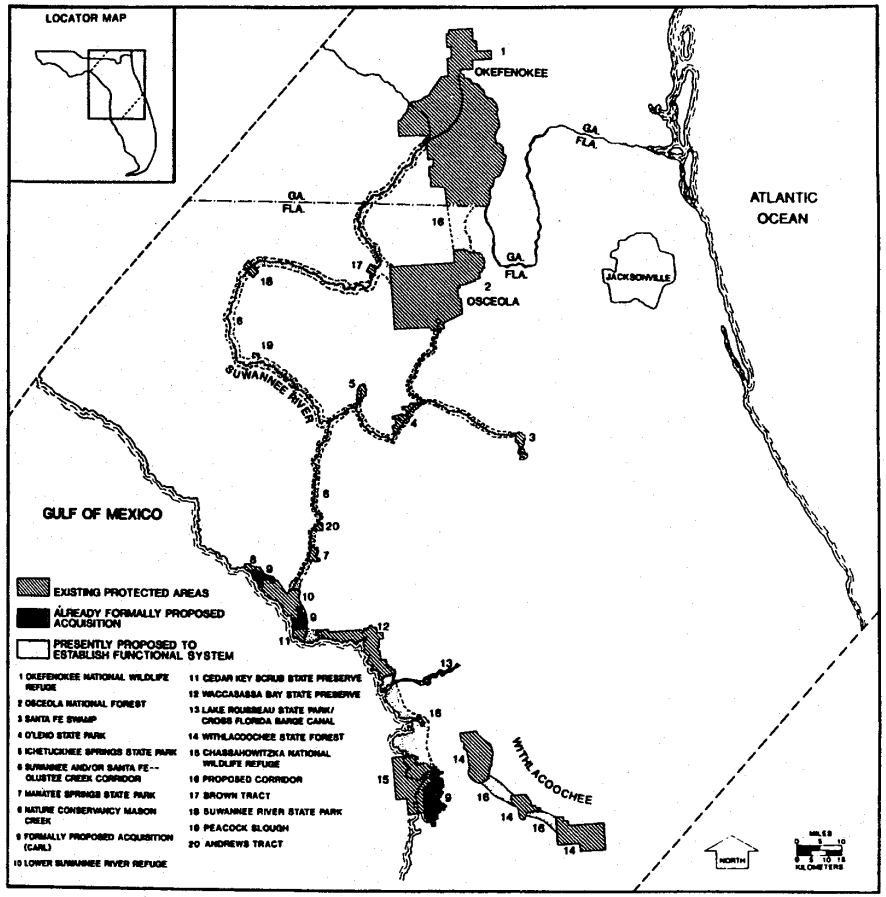


FIGURE 5.7 A MUM network, or regional network of reserves, based on the Suwannee River and its tributaries. From Noss and Harris (1986). Used with permission.

CORE RESERVES

Core reserves are the backbone of a regional reserve system. Without strictly protected areas representing most of a region's biodiversity, losses are inevitable. Criteria and methods for selecting core reserves were reviewed in Chapter 4. Size and scale issues—how much do we need?—and general management principles will be discussed later in this chapter.

Just what is a core reserve? National parks, wilderness areas, research natural areas, state parks and preserves, BLM areas of critical environmental concern, national wildlife refuges, Nature Conservancy and Audubon

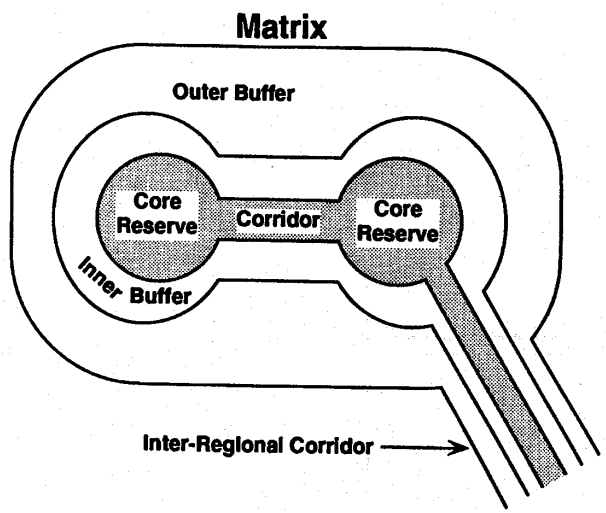


FIGURE 5.8 A model regional reserve network, consisting of core reserves, connecting corridors or linkages, and multiple-use buffer zones. Only two core reserves are shown, but a real system may contain many reserves. Inner buffer zones would be strictly protected, while outer zones would allow a wider range of compatible human uses. In this example, an interregional corridor connects the system to a similar network in another bioregion. "Matrix" refers to the landscape surrounding the reserve network. From Noss (1992b). Used with permission of the Cenozoic Society.

Society preserves, and several other kinds of areas may qualify. Recall that Scott *et al.* (1993) (see Chapter 4) considered four categories of land protection in the gap analysis project. The highest category, what we would call *core reserves,* includes any area "that is maintained in its natural state and within which natural disturbance events are either allowed to proceed without interference or are mimicked through management" (Scott *et al.* 1993). Most national parks (or parts thereof), Nature Conservancy preserves, and Audubon sanctuaries meet these criteria, but only some Forest Service wilderness areas, national wildlife refuges, and research natural areas (the latter often fail particularly because they are too small).

We suggest that changes in management, for example removal of livestock from wilderness areas and wildlife refuges, are necessary to make these areas qualify as the core reserves they should be. Design and management guidelines for core reserves will vary on a case-by-case basis.

MULTIPLE-USE BUFFER ZONES

In most regions, a system of core reserves will be necessary but not sufficient to maintain biodiversity. They must be complemented by multiple-use lands. Buffer zones also provide an opportunity to find ways to integrate development (and human activities in general) with conservation. Humans are as much a part of the earth as any other species. We just have to relearn how to get along with our nonhuman kin. What better place to relearn these lessons than in seminatural wildlands? Integration has yet to be fully realized, but there are some promising experiments, such as the Sian Ka'an Biosphere Reserve on Mexico's Yucatan Peninsula. This reserve, which contains 1.3 million acres of tropical moist forests, marshes, mangrove swamps, and freshwater and marine systems, is essentially pristine but supports about 800 people in subsistence farming, fishing, and small-scale tourism (Tangley 1988). Promising experiments in the United States are virtually nonexistent. We will have to create them.

A multiple-use buffer zone, as we define it here, is a zone that permits a greater range of human uses than core reserves but is still managed with native biodiversity as a preeminent concern. Because its allowable uses are less intense than in the general landscape matrix, it should serve to shield or insulate core reserves from harmful activities. Because road access is a major threat to sensitive species and creates many other ecological problems (see Chapter 2), road density in buffer zones should be kept low (certainly no more than 0.5 miles per square mile). Allowable activities in buffer zones might include nonmotorized recreation (including fishing and hunting, unless they pose a threat to sensitive species), selection forestry, light grazing (for grassland types that are adapted to grazing), and small-scale subsistence agriculture.

Ecologically, buffer zones serve a number of potential functions (Noss 1992b). Especially in the case of small reserves, they may ameliorate edge effects that would otherwise be intense near reserve boundaries. Wind, sun, exotic weeds, agricultural chemicals, noise, and opportunistic predators that thrive in suburban landscapes might all be filtered out by well-managed buffer zones. For large reserves, such edge effects are not expected to be as much of a problem, but a buffer from intensive logging and other commodity production will help protect sensitive species.

Ideally, buffer zones enlarge the effective size of a reserve and provide some temporal stability to the landscape. As noted earlier, we can expect many species to be able to persist in multiple-use landscapes. Reserves are needed mainly for the more sensitive species and to provide a buffer against our ignorance about the conditions that species need to survive. Because all

environments are dynamic, a buffer zone may have to take on the functions of a reserve if disturbances temporarily make reserve habitats unsuitable. A lightly used buffer zone will be easier to convert to reserve functions than would a massive industrial clearcut, soybean field, or housing subdivision. Buffer zones can also provide connectivity between reserves, allowing animals to move long distances without molestation or a high chance of mortality on busy roads. Even if buffer zones are technically population sinks for some species (i.e., areas where death rates exceed birth rates), they can still contribute to overall metapopulation peristence by at least temporarily supporting resident individuals while serving as connections between source habitats (see Pulliam 1988, Howe *et al.* 1991).

Opportunities for creating buffer zones appear most promising in regions where vast areas of national forest or BLM lands surround national parks, wilderness areas, and other reserves. Reducing road density and eliminating or scaling down harmful activities such as logging, mining, livestock grazing, and off-road vehicle use on these lands are needed. Politically, such changes will not be easy. In many cases the Forest Service has vigorously opposed the idea of buffer zones. The Park Service and Forest Service have maintained an antagonistic relationship throughout their histories (Grumbine 1990a, 1991). The national forests will not serve as buffer zones for national parks without sweeping changes in national leadership and agency organization (for example, moving the Forest Service from the Department of Agriculture back to the Department of Interior, as is often proposed).

Where reserves are surrounded by private lands, buffer zones may seem more difficult to establish. However, creative solutions are possible. Farmers, for example, might be paid easements to maintain perennial cover (such as pasture) on their lands that border reserves. County planning boards can zone for low-density developments (e.g., agricultural zoning) and limit road construction in areas surrounding reserves. High-density developments, although desirable for other environmental reasons (they save space and energy), should be kept away from reserves and other sensitive sites, for they will be sources of noise, chemicals, housecats, and opportunistic predators like raccoons and human trespassers.

Connectivity

Connectivity is fundamental to our concept of regional reserve networks. Biological functions of connectivity have been discussed in some detail (e.g., Harris and Gallagher 1989; Hudson 1991; Saunders and Hobbs 1991; Noss 1992b, 1993b) and have been vigorously debated (Soulé and Simberloff 1986, Noss 1987c, Simberloff and Cox 1987, Noss 1991c, Simberloff *et al.* 1992).

Despite uncertainty about optimal width of corridors, mortality risks, tradeoffs with other uses of conservation dollars, and other issues, the fundamental need for populations of many species to be connected in order to be viable is widely recognized. Determining the best ways to provide connectivity, however, is a tremendous challenge.

Connectivity is essentially the opposite of fragmentation. Instead of breaking landscapes into pieces, we are seeking ways to preserve existing connections and restore severed connections. The connectivity of interest to biologists and conservationists is *functional connectivity,* usually measured according to the potential for movement and population interchange of target species. Many factors determine the degree of functional connectivity between habitat patches in a landscape (Table 5.1). Variation in the quality of linkages affects their use by organisms (Henein and Merriam 1990).

Connectivity is not just corridors. For species that disperse in more or less random directions, such as the northern spotted owl (Thomas *et al.* 1990) or cabbage butterfly (Fahrig and Paloheimo 1988), connectivity is affected more by the suitability of the overall landscape matrix than by the presence or absence of discrete corridors. Multiple-use buffer zones with low road density and minimal human disturbance, as described earlier, should provide adequate connectivity for most organisms. Scale must be specified in discussing connectivity. A multiple-use landscape 20 or even 50 miles wide that lies between two national parks can be considered a corridor at a regional scale, if in fact it functions as such. Biogeographers discuss corridors as broad, heterogeneous zones, such as the Bering Land Bridge, that permit migration of species from one region to another over long periods of time (Brown and Gibson 1983). For conservation planning, connectivity

Table 5.1 Determinants of Functional Connectivity

Mobility or dispersal characteristics of the target species Species-specific habitat preferences for movement Dispersal distance or scale of resource utilization Rate of movement or dispersal (through various types of habitats)
Other autecological characteristics of the target species (e.g., preference for particular plant species or structural features of the habitat; feeding and nesting requirements; mortality risks)
Landscape context: Structural characteristics and spatial pattern of landscape (patch, corridors, matrix, mosaics)
Distance between patches of suitable habitat
Presence of barriers to movement (e.g., rivers, roads)
Interference from humans, predators, etc.

should be evaluated at several spatial and temporal scales, ranging from daily movements within home ranges to long-distance dispersal events connecting populations once every generation or two. Critical planning and management questions exist at each of these scales.

For corridors or other habitat linkages to serve conservation goals, their functions must be stated explicitly and analyzed carefully (Soulé 1991b). The scientific literature on connectivity has concentrated quite narrowly on discrete habitat corridors and specifically on a conduit function: allowing individuals of a target species to move from one place to another. But a habitat linkage in a real landscape may have several functions and affect many species. Although a particular target species may be the main concern in a corridor plan, the net effect of alternative landscape designs on a whole suite of species and ecological processes should be considered, whenever possible. Two major roles of landscape linkages (defined here as specific pieces of land that provide a connectivity function) in biological conservation are to: (1) provide dwelling habitat for plants and animals and (2) serve as a conduit for movement. The conduit role can be further subdivided into several functions: (a) permitting daily and seasonal movements of animals; (b) facilitating dispersal, consequent gene flow between populations, and rescue of small populations from extinction; and (c) allowing long-distance range shifts of species, such as in response to climate change. These functions have been discussed by Noss (1993b) and are summarized below.

Linkages as habitat. Some types of linkages, such as riparian forests, are distinct in the natural landscape. Riparian forests have many ecological values, including rich alluvial soils and an associated high biological productivity; microclimates moderated by a dependable source of water; abundant insects and plant foods such as woody browse or mast for vertebrates; and many tree cavities and substrates to serve as homes or nests for birds and mammals (Harris 1989). Riparian forests and other naturally linear habitats would be important to protect even if they served little as movement corridors (Harris and Gallagher 1989).

Wide protected linkages are basically extensions of core reserves. The width of corridor needed to contain an adequate amount of interior habitat and minimize edge effects and mortality rates is uncertain and depends on habitat type and quality both within and outside the corridor (Noss 1983, 1987c, 1993b) and on the target species and the mortality risks it faces (Soulé 1991b, Soulé and Gilpin 1991). Another consideration for determining optimal linkage width is the territory or home range size of target species, particularly when the length of the linkage exceeds normal dispersal distances

(Bennett 1990; Harrison 1992; Noss 1992b, 1993b). This issue will be discussed later under "linkages for dispersal."

Linkages for movements within home ranges. Movement of animals between reserves or other suitable habitat patches is the function most often associated with corridors (Soulé and Gilpin 1991). A core reserve may not encompass a single annual or even a daily home range of a large mammal. Maintaining safe travel opportunities for wide-ranging species is largely a matter of protecting them from human predation and road mortality. Every species faces mortality risks when moving about its home range on a daily or seasonal basis. Minimizing sources of mortality—human activity, internal fragmentation of corridors, ambush sites for predators—is a major consideration in corridor design for target species (Noss 1987c, Simberloff and Cox 1987, Soulé 1991b, Soulé and Gilpin 1991).

Vertebrates, especially certain ungulates, often use traditional migration routes between summer and winter range. Elk, for example, generally use forested travel lanes, if possible, for migratory movements (Adams 1982). Mule deer also commonly use distinct corridors for travel between winter and summer range (Thomas and Irby 1990). Tunnels or underpasses have been built under highways to facilitate deer movements in several regions (Reed *et al.* 1975, Reed 1981).

Highways can be significant mortality sinks for many animals. In southern California, seven of thirty-five radio-collared cougars were killed by automobiles in the first two years of a study (Beier and Barrett 1991). Several animals have been documented using corridors, especially canyon bottoms with dense vegetation. Cougars used canyon corridors 0.5 to 1.0 km wide and 6 km long and crossed under interstate highways by way of culverts. Some animals that failed to use culverts were killed on the highway (Beier 1993, Harrison 1992). But other studies found that cougars used bridge underpasses but not culverts; animals crossed roads rather than pass through culverts (P.J. Mock, personal communication). Similar to the situation in southern California, the greatest source of mortality for Florida panthers is roadkill (Harris and Gallagher 1989). The Florida panther uses wooded strands and other natural corridors in the south Florida landscape for movement (Maehr 1990). Panthers and dozens of other vertebrate species regularly use wildlife underpasses built on Interstate 75 across the Big Cypress Swamp (Foster and Humphrey 1991).

Animals such as amphibians that use different habitats in a landscape for different life history stages also depend on connectivity. Small "toad tunnels" have been used in several European countries for decades to help

migrating amphibians avoid the hazards of road crossings (Langton 1989). Aquatic turtles may migrate hundreds of meters from rivers or ponds to find sandy substrates in which to lay their eggs. Conversely, in times of drought, many upland animals move downslope to riparian areas (Brown *et al.* 1987). If habitat in between is fragmented (for example by a highway) they may not be able to make such movements safely.

Linkages for dispersal. Dispersal refers to movement of organisms away from their place of origin, such as the movement of subadult animals out of the parental home range. Dispersal can potentially counteract the isolating effects of habitat fragmentation, but only if adequate dispersal habitat remains. For a regional metapopulation of a species to persist, enough individuals must move between patches to balance extirpation from local patches (den Boer 1981, 1990). Preserving natural linkages between existing populations may increase the chance of metapopulation persistence. Dispersal linkages are most important for late-successional species (which commonly have poor dispersal capacities), other habitat specialists, and for species such as large carnivores that risk being killed by humans or vehicles in developed landscapes. Dispersal is more likely to be successful when habitat in a linkage is similar to the habitat in which a species lives (Wiens 1989). But desert-dwelling mountain sheep will move across basins from one mountain range to another if mountainous corridors are lacking (Bleich *et al.* 1990).

Linkages that support resident populations of animals may be more likely to function as long-distance dispersal conduits for those species. Genes might then flow in both directions, filtering through resident breeding animals, and minimum corridor widths can be based on average home range or territory diameters of target species (Bennett 1990; Harrison 1992; Noss 1992b, 1993b). The notion of maintaining dispersal corridors wide enough to support resident individuals or pairs of target species is controversial. A model by Soulé and Gilpin (1991) predicts that animals in wide corridors may spend time wandering around rather than reaching their goal, but such models may not be accurate for most vertebrates (Noss 1993b).

The wide-corridor strategy has been proposed specifically for cases where the distance between population centers exceeds normal dispersal distances for the target species. A wide corridor of suitable habitat appears to be optimal under such circumstances. Logically, the ideal connectivity is continuity. Unless resident individuals of a target species exist within linkages or within a series of stepping-stone habitats—none separated by impenetrable barriers or distances greater than those commonly traversed—the populations will be isolated from one another. Interchange necessary to

maintain the metapopulation must then take place through translocations, an expensive and uncertain long-term undertaking, especially when applied to multiple species.

When long-distance dispersal corridors are designed, all of an animal's life-history requirements should be appraised (Beier and Loe 1993). A culvert or underpass will not suffice. Consider the cougar, with an average female monthly home range of 43 km^2 (10,625 acres) and an average annual home range of 155 km^2 (38,301 acres, range 24,463–87,227 acres) in southern California; male annual home ranges average about 450 km^2 or 111,120 acres (P. Beier, personal communication). To accommodate a female monthly home range twice as long as it is wide (based simply on the observation that ranges are commonly rectangular or elliptical), a linkage would need to be about 3.1 miles wide (Harrison 1992). Linkages would need to be wider to accommodate the larger, nonoverlapping home ranges of males. Because male cougars disperse longer distances and make longer intrarange movements (Anderson 1983), one male may be able to mate with several females.

Although intuitively attractive and suggested independently by several authors, the idea of basing dispersal corridor widths on home range diameters is not supported by much empirical evidence. Nevertheless, a prudent strategy would be to maintain or restore wide habitat corridors whenever the intent is to link areas farther apart than normal juvenile dispersal distances. It is expected that inhabited linkages will be internally heterogeneous and might contain many bottlenecks (for example, highway underpasses) without seriously limiting their effectiveness. Interregional dispersal corridors for large carnivores, such as those proposed for grizzly bears in the northern Rocky Mountains which link population centers up to 150–200 miles apart (see Noss 1992b, Shaffer 1992), must necessarily consist of landscapes many miles wide with low road density in order to protect animals from poachers.

To summarize, a lesson of dispersal studies for reserve network design is that reserves or population centers of target species should be connected by linkages of suitable habitat. If no corridors are possible, reserves should be very close together and not separated by insurmountable barriers (Diamond 1975, Thomas *et al.* 1990). Reserves separated by distances longer than normal dispersal distances of target species should contain resident individuals or populations between them, either distributed more or less continuously or in stepping stone habitats. For species that refuse to cross even a few meters of unsuitable habitat, such as a road (Mader 1984, Swihart and Slade 1984, Mader *et al.* 1990), continuous habitat linkages are needed both for movements within home ranges and for dispersal. Even some birds, despite their ability to fly, will not cross areas of unsuitable

habitat (Diamond 1975). In all cases, the scale of planning must correspond to the scale at which organisms use the environment.

Linkages for long-distance range shifts. Another potential function of connectivity is to provide for long-distance migration of species in response to climate change. Many temperate plant species have migrated hundreds of miles northward or hundreds to thousands of feet upward in elevation since the Pleistocene (e.g., Davis 1981). Models of global warming predict dramatic shifts in habitat conditions in most regions over the next few decades. But human activities have imposed a new set of barriers on the landscape that, in addition to natural barriers, may interfere with long-distance movements. If rates of global warming in the next few decades are as fast as predicted, many species will be unable to migrate quickly enough, even along ideal corridors. Species with short and rapid life histories, such as introduced weeds, will probably adjust well to climate change, as will broadly distributed species. But species with limited and discontinuous distributions or poor dispersal capacities are at high risk of extirpation (Peters and Darling 1985, Peters 1988, Peters and Lovejoy 1992).

Mountainous regions with broad elevational spans provide better opportunities for adaptation to climate change than flatter regions. A 3° C rise in temperature (as is predicted to occur with greenhouse warming) translates to a latitudinal range shift of roughly 250 km (155 miles), but an elevational range shift of only 500 m (1640 feet) (MacArthur 1972). Perhaps the best way to facilitate adaptive migration in response to climate change is to maintain intact environmental gradients. Complete, unfragmented elevational gradients will offer opportunities for species to migrate upslope in response to global warming. The full spectrum of topoclimates and substrates should also be maintained in each landscape, so that species can adjust distributions to changes in temperature and soil moisture conditions, as controlled by topography, aspect, and soil characteristics. Ultimately, habitat continuity on a continental scale will be needed to facilitate movement of entire floras and faunas in response to climate change.

From Regional to Continental Networks

Reserve networks with the components described above—core reserves, buffer zones, and connectivity—can be implemented at many scales, from counties to continents. We emphasize a regional scale of planning for reasons expressed throughout this book: regions are often physiographically or biogeographically distinct, they provide a convenient scale for mapping and analysis, and they inspire a sense of belonging and protectiveness in their more enlightened human inhabitants.

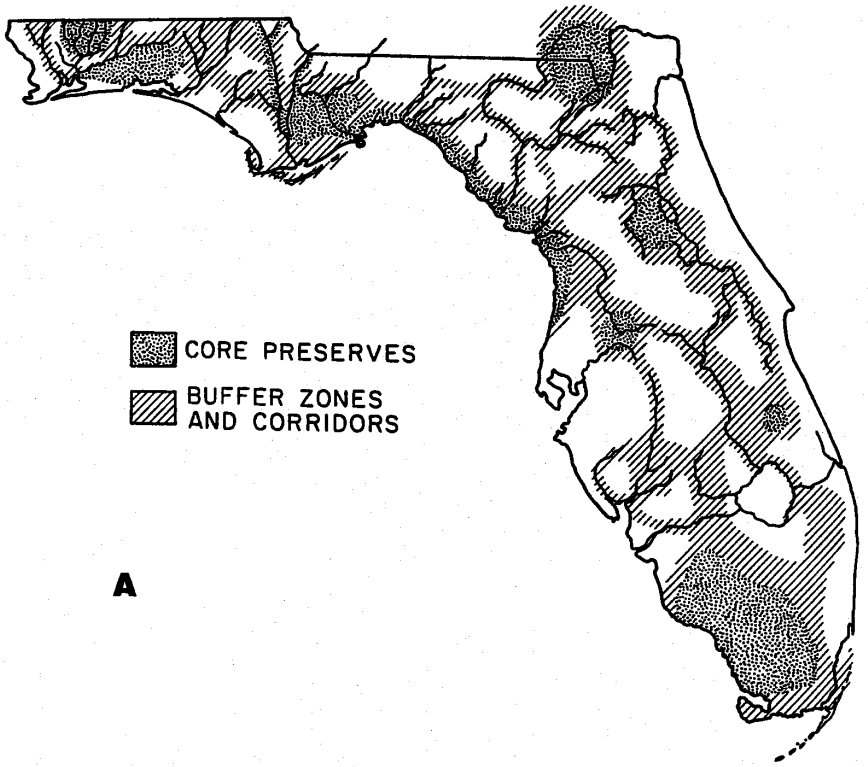
The Wildlands Project, mentioned earlier, is an effort to stimulate and promote bioregional conservation planning throughout North America. The Wildlands Project is a continental-scale venture built from a collection of regional reserve networks. Many regional conservation plans are being developed by local people. Examples of proposed regional networks are shown for Florida (Fig. 5.9), the southern Appalachians (Fig. 5.10), and the northern Rocky Mountains (Fig. 5.11). Another example, for the Oregon Coast Range (Noss 1992c, 1993a), was provided in Chapter 4 (Fig. 4.4). We emphasize that all of these proposals are preliminary and need refinement. But this is the strategy of The Wildlands Project and of regional network planning in general: Put forth a bold vision of what it might take to maintain all of biodiversity in a region and then work out the details later. The vision will provide direction and motivation for all subsequent work.

Size and Scale of Networks

What does it take to maintain in perpetuity all of biodiversity in a region? This is a complex question. Though it has occupied the minds of conservation biologists since the SLOSS controversy and, in some cases, much earlier (Shelford 1933, Kendeigh *et al.* 1950–51), there is no general answer. Usually the question has been framed for single reserves and one group of organisms. For instance, how big a reserve do we need to maintain populations of neotropical migrant birds? But we now know that single-reserve analyses are incomplete, especially when species are distributed as metapopulations. For birds, the regional abundance and spatial pattern of forest, not just the size of individual forest tracts, are necessary considerations because dispersal of birds from other forests can be important in maintaining populations (Askins *et al.* 1987). Unless suitable habitats are truly isolated, with no interchange between them, we must consider size and scale in a regional context.

Some general considerations for determining optimal size and scale of reserve networks have been presented. They include all the criteria for capturing hot spots and representing ecosystems discussed in Chapter 4 and criteria for maintaining viable populations of those species with the largest area requirements (typically large carnivores). They also include allowing for the operation of natural disturbances and other key processes and maintaining opportunities for organisms to migrate and otherwise adjust their distributions to changing environments.

We recommend that a draft reserve system first be designed to meet the representation objectives discussed in Chapter 4. This draft system would include at least one representative of each major habitat or vegetation type,



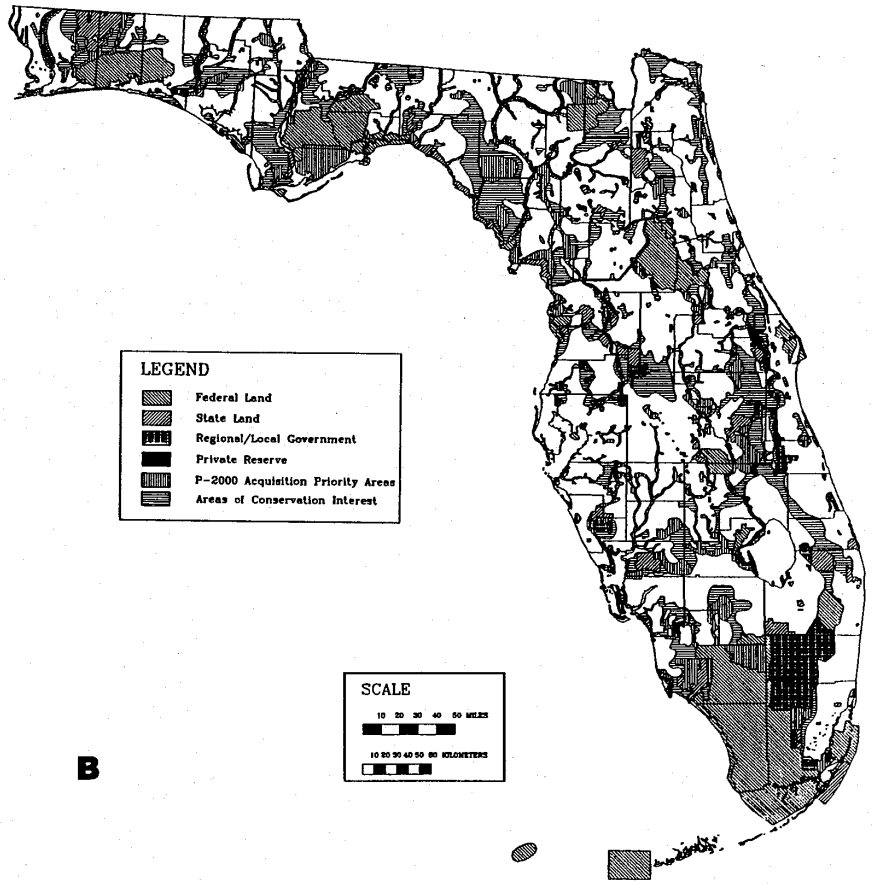


FIGURE 5.9 (A) A proposed reserve network for Florida. The system was designed to capture hot spots of endemism and large areas with low road density, and to provide for movements of wide-ranging species, especially Florida panther and black bear (modified from Noss 1987a). (B) Ecological Resource Conservation Areas, showing existing public lands, private reserves, proposed state acquisitions, and areas of conservation interest, as determined by a 1991 workshop sponsored by The Nature Conservancy, Florida Audubon Society, and Florida Department of Natural Resources. Used by permission of the Florida Natural Areas Inventory.

and, for those taxa with distributional data available, at least one population of every extant species native to the region. Depending on the biogeography of the region, the draft system based on these objectives might include some 10 to 50 percent of the total land area, or in rare cases much more (Ryti 1992).

The next step is to identify the species with the largest area requirements and figure out what it takes in area and connectivity to provide a high probability for maintaining their populations for several hundred years. This step might involve formal population viability analyses (see Soulé 1987, Boyce 1992), or if not enough demographic data exist (as is often the case), area requirements should be estimated on the basis of the best available information and professional judgment of conservation biologists. Finally, one should distinguish the processes necessary to maintain healthy ecosystems in the study region, such as hydrological and disturbance–recovery regimes, and determine how much more area is needed for these processes to operate effectively.

We hasten to note that strictly protected core reserves are not needed to serve all these functions. Most species and processes will probably persist

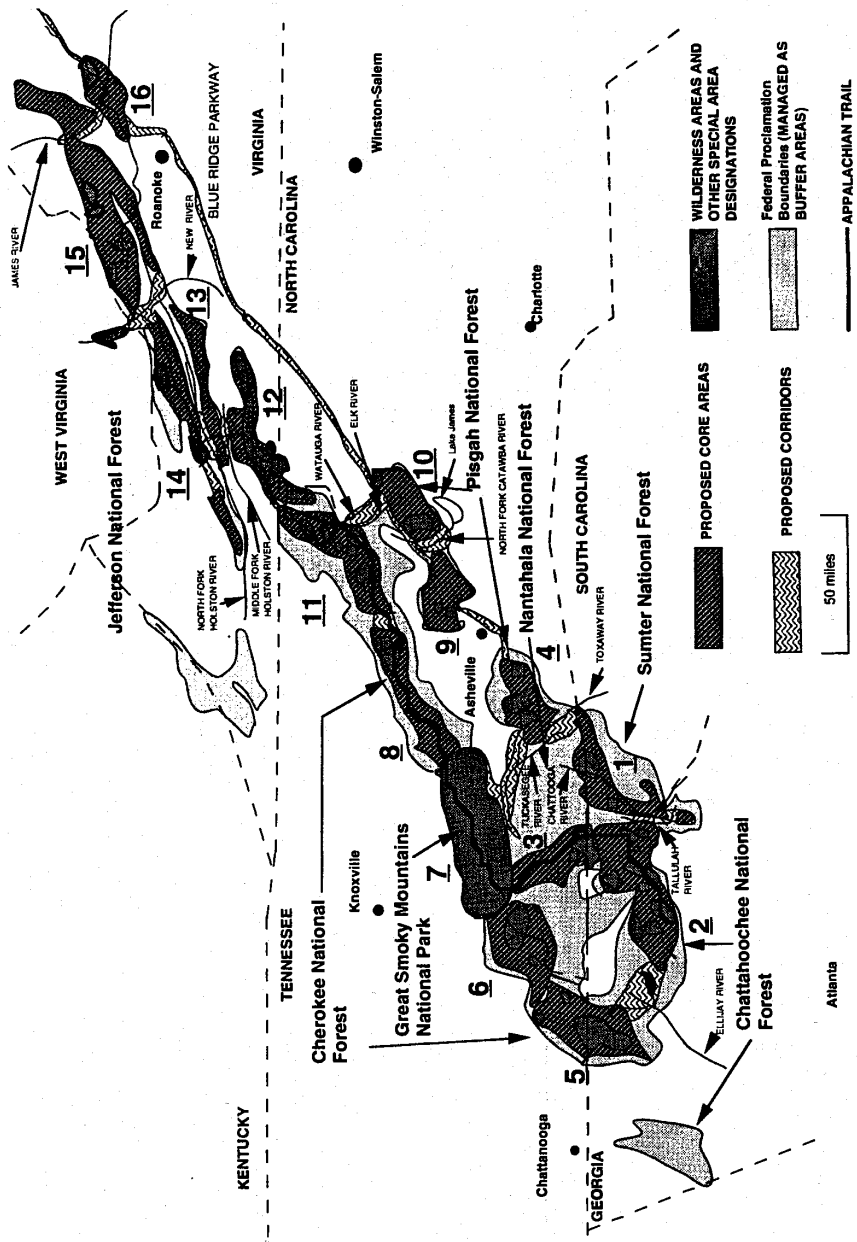


FIGURE 5.10 Proposed core and corridor areas in the Blue Ridge Province of the Southern Appalachian Bioregion (from Newman *et al.* 1992). Used with permission of the authors and the Cenozoic Society.

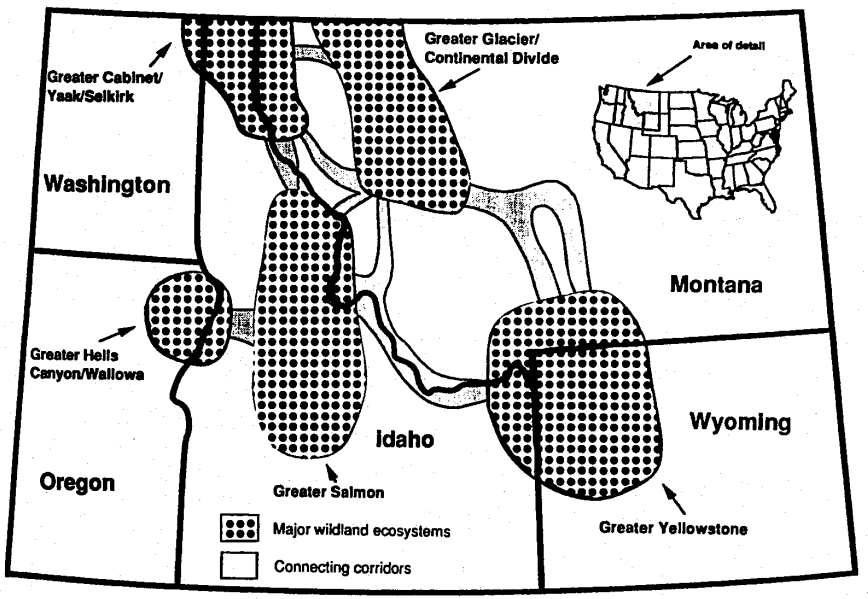


FIGURE 5.11 Conceptual plan for protecting and linking major wilderness areas in the northern Rocky Mountains, as proposed by the Alliance for the Wild Rockies. Used with permission.

in well-managed buffer zones. However, a conservative approach would represent each ecosystem type at least once in core reserves and create a secure network of reserves for large carnivores and other species that are especially sensitive to human activity.

Area Requirements of Large Carnivores

Regional conservation plans, such as those being developed in cooperation with The Wildlands Project, often focus on large carnivores. Species that need a large amount of secure, wild habitat to maintain viable populations should receive priority attention in a regional plan. Otherwise, they will not be around for long. Often, they have already been extirpated and decades of wilderness recovery will be needed to bring them back. Many American conservationists have recognized the significance of large carnivores. The following quotes from prominent ecologists reinforce the point that carnivores deserve special attention:

> The animals requiring first and most careful consideration are the carnivores, likely to be unpopular with the agricultural (broad

> sense including game culture) interests outside the park or forest. (Shelford 1933: 244)

> The National Parks do not suffice as a means of perpetuating the larger carnivores; witness the precarious status of the grizzly bear, and the fact that the park system is already wolfless . . . The most feasible way to enlarge the area available for wilderness fauna is for the wilder parts of the National Forests, which usually surround the Parks, to function as parks in respect to threatened species. (Leopold 1949: 276–277)

> It is in the absence of the large predators that many sanctuaries are not entirely natural and have unbalanced populations of the various species. Very large sanctuaries are required to contain the large predators. (Kendeigh *et al.* 1950–51)

The decline of large carnivores in North America is unprecedented in its rapidity. Within a few decades after permanent settlement by Europeans, cougars and wolves were essentially gone from the East and grizzly bears were absent from most of the West. The extirpation of these species was a consequence of deliberate extermination, promoted by bounties. The Florida panther, virtually extinct, is the last remnant cougar subspecies east of the Mississippi River, though scattered reports from further north are common and may involve western cougars released from captivity. The red wolf was extinct in the wild until recently reintroduced to two areas in the Southeast. Jaguars are gone from the Southwest, except occasional strays that may be trying to escape habitat destruction or hunters in Mexico. The grizzly bear and gray wolf have both been eliminated from over 90 percent of their ranges in the lower 48 states. The same appears to be true for the elusive wolverine. Even black bears have suffered a severe range contraction (Schoen 1990).

Aldo Leopold, especially in his later years, emphasized large carnivores in his writings because he recognized that these predators provide a critical test of society's commitment to conservation (Meine 1988, 1992). It is relatively easy to save a patch of wildflowers or even a few thousand acres of woods for songbirds. No one will call such actions radical. But to advocate protecting millions of acres of roadless habitat for creatures capable of maiming and eating people, even though they do so rarely, requires an extraordinary sense of humility, ecological conscience, and courage.

Leopold also knew from his field observations that a vigorous population of large carnivores is a sign of healthy land. Carnivores at the top of the food chain are correctly considered keystone species, umbrella species, flagship species, and supreme indicators of success in conservation. In some situations, say Long Island or central Illinois, opportunities for predator recovery are unlikely for many years to come. But across much of the United States, including heavily populated areas such as Florida (Noss 1987a) and southern California (Beier 1993), short-term viable populations of at least one large carnivore—cougar—could be reestablished without radical changes in land use. Long-term population viability for these species, however, will require more drastic changes. In any case, a regional conservation plan that fails to create conditions favorable for native carnivores is incomplete.

What would it take to restore long-term viable populations of large carnivores? The estimates may alarm some people. Probably tens of millions of acres of wild habitat are needed for long-term persistence. Schonewald-Cox (1983) estimated that large carnivores require reserves on the order of 1–10 million hectares (2.5–25 million acres). Assuming a short-term minimum viable population of 50, Hummel (1990) estimated that grizzly bear populations in Canada require an average of 49,000 km^2 (12.1 million acres), wolverines about 42,000 km^2 (10.4 million acres), and wolves about 20,250 km^2 (5 million acres).

Grizzly bear densities in the northern Rockies of the United States are somewhat higher than the Canadian average. Assuming four bears per 100 square miles, Metzgar and Bader (1992) calculated that 50,000 square miles (32 million acres) of wild habitat are needed to maintain 2000 grizzly bears in the northern Rockies. This population corresponds to an effective population of only 500 bears, the official U.S. Fish and Wildlife Service recovery goal for the species. As for many mammals and birds, an effective breeding population of grizzlies is about one-quarter of the total population, largely because individuals do not contribute equal amounts of genetic material to the next generation (Allendorf *et al.* 1991). The required area of 32 million acres for a long-term viable population is roughly 60 percent of the U.S. northern Rockies region.

An analysis of recovery requirements for the Florida panther, which once ranged throughout the Southeast, came to similar conclusions (Noss 1991f). A genetically effective population of 50 panthers, which would have a reasonable chance of short-term survival, translates to an actual adult population of 100–200 (Ballou *et al.* 1989). For calculating reserve area, it is useful to focus on male panthers because they have larger and nonoverlapping home ranges that usually encompass the overlapping ranges of one or more females. Assuming an adult sex ratio near unity (generally true for cougar populations; Anderson 1983), a reserve network for short-term viability of panthers should provide for 50–100 males. Given an average male

home range of 558 km² (137,600 acres) (Maehr 1990), each reserve network would have to encompass about 6.9 to 13.8 million acres. To provide a margin of safety, this estimate was rounded upward to 10 to 15 million acres (Noss 1991f). But again, this is only the area needed for short-term viability. For long-term persistence, the U.S. Fish and Wildlife Service (Jordan 1991) again calls for an effective population of 500, which (they fail to note) translates to 1000–2000 adult panthers requiring a total of 100-150 million acres of wild land (Noss 1991f). This is about the size of the entire states of Florida, Georgia, South Carolina, and Alabama combined, or roughly 60–70 percent of the original range of the Florida panther in the Southeast. Whether or not this much land is really needed for long-term persistance of the panther is uncertain, of course. But given the available data, it is a credible hypothesis.

Single reserves of 100–150 million acres are highly unlikely anywhere in temperate North America in the near future. But the problem becomes less daunting when we recognize that viable populations of panthers and other large carnivores need not be contained within single reserves. Rather, they can be distributed over a much larger area, but in much smaller units, as a metapopulation. This is where the concept of regional reserve networks comes into play.

From what we can gather from historical records, populations of many large carnivores were virtually continuous across much of their presettlement ranges in North America. Most of these species are habitat generalists, limited mainly by food supply, human persecution, or social behavior (territoriality or mutual avoidance). Areas of unsuitable habitat, such as desert playas and high peaks, were only partial barriers to movement. Cougars commonly disperse distances of 100 miles or more (Anderson 1983) and usually seek cover in riparian vegetation or other shelter when moving across broad areas (Young 1946). Therefore, populations and even classified subspecies of cougars, wolves, bears, and other carnivores were probably genetically connected by occasional dispersal over immense areas. Population viability of these species should not be analyzed within single parks, watersheds, or even physiographic regions, but instead across a scale of habitat that corresponds to the genetic and demographic structure of the species. This often will mean several interconnected regions, for example, the entire southeastern United States for the Florida panther and the entire Rocky Mountains for the grizzly bear.

Noss (1991f) suggested that the recovery goal of an effective population of 500 panthers, or 1000–2000 adults, could be met by establishing 10 smaller populations of 100–200 panthers, each requiring about 10–15 million

acres (or perhaps less, if areas where panthers are reestablished support higher prey densities than in the South Florida habitats where home range sizes were calculated). The system could be managed as a "metapopulation of metapopulations" in reserve networks. Each regional reserve network would consist of several core reserves and buffer zones linked by wide habitat linkages that would permit dispersal movements. How land is apportioned among reserves would depend on the distribution of suitable and restorable wildland relative to developed areas. These small metapopulations would be connected by restored long-distance linkages, which can be developed over the next few decades, to enhance long-term persistence of the larger metapopulation of 1000–2000 adults across the Southeast. If necessary to prevent genetic problems before interregional linkages are restored, individual animals can be translocated from one population to another (translocations for this purpose have now been approved for recovery of the Florida panther).

Area Requirements for Natural Disturbance Regimes

A small reserve is vulnerable even to natural events. One lightning strike, for example, could result in a fire that destroys the last stand of old-growth forest in an eastern state. For a forest type, such as ponderosa or longleaf pine, that requires frequent fire to persist, the low chance of lightning striking a small, isolated reserve is just as great a threat. Without fire, fire-sensitive species will invade and radically change community structure. For these kinds of reasons, small reserves usually require more intensive management to maintain the conditions for which they were set aside (Pyle 1980, White and Bratton 1980).

How big does a reserve need to be to maintain a natural disturbance regime? First, it is helpful to visualize a landscape as a "shifting mosaic" of patches in various stages of recovery from disturbance (Cooper 1913, Watt 1947, Bormann and Likens 1979). Shifting mosaics in forest ecosystems will be considered in more detail in Chapter 6. For now, we need only recognize that reserves that are small relative to the spatial scale (patch size) of disturbance may experience dramatic fluctuations in the proportions of different seral stages over time, which in turn may threaten populations that depend on certain stages. If a core reserve is to maintain a reasonably stable mix of seral stages and species, it must be large enough that only a relatively small part of it is disturbed at any one time. Another requirement is that a source of colonists (that is, a reproducing population of the same species) exists within the reserve or within dispersal distance so that populations can

be reestablished on disturbed sites. Optimal reserve size can therefore be estimated by knowing something about the scale of natural disturbance and the landscape context in which the reserve exists.

Pickett and Thompson (1978) defined a "minimum dynamic area" as "the smallest area with a natural disturbance regime, which maintains internal recolonization sources, and hence minimizes extinction." In theory, a minimum dynamic area should be able to manage itself and maintain habitat diversity and associated native species with no human intervention. Shugart and West (1981) estimated that landscapes must be some 50–100 times larger than average disturbance patches to maintain a relative steady state ("quasi-equilibrium") of habitats. In a steady-state landscape, the proportions of seral stages in the overall landscape would be relatively constant over time, even though the sites occupied by different stages would change.

A limitation of the Shugart and West model is that all disturbances are assumed to be the same size, whereas real disturbance regimes create a range of patch sizes, increasing diversity (Baker 1992a). Furthermore, a steady state may not be a natural condition in some ecosystem types, such as those regularly experiencing large, catastrophic fires (Baker 1989). But the concept is still useful because landscapes that are close to steady state will experience less radical fluctuations in seral stages and associated species populations than smaller areas and consequently should experience fewer extinctions (Shugart and Seagle 1985). The greatest stability occurs when the disturbance interval is long compared with recovery time and only a small portion of the region is affected. Although no reserve size can guarantee stability, larger reserves have a lower probability of major shifts in landscape dynamics caused by rare disturbance events (Turner *et al.* 1993).

Keep in mind that, although absolute stability or equilibrium is not the way of nature (Botkin 1990), extreme fluctuation is also abnormal in most ecosystems and, when caused by human activity, is often what threatens biodiversity. As pointed out by Pickett *et al.* (1992):

> The new paradigm in ecology can, like so much scientific knowledge, be misused. If nature is a shifting mosaic or in essentially continuous flux, then some people may wrongly conclude that whatever people or societies choose to do in or to the natural world is fine. The question can be stated as, "If the state of nature is flux, then is any human-generated change okay?" . . . The answer to this question is a resounding "No!" And the resonance is provided by the contemporary paradigm and the ecological knowledge that underwrites it. Human-generated changes must be constrained because nature has *functional, historical,* and *evolutionary* limits. Nature has a range of ways to be, but there is a limit to those ways, and therefore, human changes must be within those limits.

Baker (1992a) proposed that perpetuation of natural disturbance regimes should be a fundamental design goal of nature reserves. Attributes of disturbance regimes and associated landscape patterns are essential, higher order expressions of biodiversity. One need not defer to species-level concerns, as did Pickett and Thompson (1978), in defining minimum dynamic areas, but can look to the landscape directly (Baker 1992a). For example, a certain disturbance-produced mosaic of seral stages might be needed to maintain viable populations of moose in a region, but that mosaic is also an expression of landscape diversity in its own right.

Although no one can specify exactly how large a reserve should be relative to natural disturbance regimes, large reserves will minimize management problems because (1) disturbances will not affect an entire reserve at once, leaving it open to invasion by weedy species; (2) disturbances will be less likely to spread from the reserve into adjacent human-occupied lands; and (3) the natural size distribution of disturbances will not be truncated by suppression at reserve boundaries (Baker 1992a). Besides size considerations, locating a reserve so that disturbance initiation and export zones are all contained within its boundaries is sensible. Disturbances can then be allowed to run their course without suppression. Buffer zones may also help control the spread of disturbances (Baker 1992a).

Other Criteria for Scale of Wildlands

Noss (1991b, 1991d, 1992b) recently hypothesized that about 50 percent of an average region needs to be protected as wilderness, or equivalent core reserves and lightly used buffer zones, to restore populations of large carnivores and functional disturbance regimes and meet other well-accepted conservation goals. Noss (1992c, 1993a) subsequently calculated the acreage in proposed Class I and Class II Reserves in the Oregon Coast Range plan (see Chapter 4), as determined from a variety of criteria, and it added up to almost precisely 50 percent of this region of 5.3 million acres. It was recognized that connections to other regions (the Siskiyou Mountains to the south and Cascades to the east) would be necessary to restore viable populations of large carnivores.

Other ecologists and conservationists have converged on similar estimates of the optimal amount of wild habitat for a region. Philosopher Arne Naess proposed an ideal balance of one-third wilderness with no human habitation, one-third "free nature" (containing mixed communities of

humans and other species living in largely nondomesticated environments), and one-third intensive human land uses (cited in Sessions 1992). Recently ecologist Malcolm Hunter has called for a similar "triad" of reserves, lightly managed forest, and intensive tree farms for forest regions (Hunter and Calhoun 1994). Ecologist Paul Sears called decades ago for 25 percent of the United States to be preserved as wilderness. More recently, authors Edward Abbey and Dave Foreman independently suggested 50 percent as a reasonable compromise (D. Foreman, personal communication).

Considering sustainability of ecosystem processes and quality of life for people, Eugene Odum (1970) recommended that 40 percent of the state of Georgia remain as natural area, 10 percent in urban-industrial systems, 30 percent in food production, and 20 percent in fiber production. Odum pointed out that Georgia is an excellent microcosm for the United States as a whole, as it has close to the mean human population density and land use patterns. Similarly, Odum and Odum (1972) proposed that half natural and half cultural land use in southern Florida was optimal ecologically, economically, and culturally. As discussed in Chapter 4, calculations of the area necessary to represent all species and ecosystem types in a region can run as high as 99 percent, but are usually in the range of 25 to 75 percent. The range of estimates is large because of inherent differences in distribution patterns of organisms among regions.

The amount of wild habitat needed to meet the conservation goals espoused in this book will vary from region to region in response to numerous factors (Table 5.2). The optimal amount of wild land will depend, in part, on the kinds and intensities of human uses on nonreserved lands and on what we consider an acceptable quality of life for ourselves as well as other creatures. However, the convergence of estimates cited above and summarized in Table 5.3 leads us to suggest that most regions will require protection of some 25 to 75 percent of their total land area in core reserves and inner buffer zones, assuming that this acreage is distributed optimally with regard to representation of biodiversity and viability of species and well connected within the region and to other reserve networks in neighboring regions. Protection should not imply a "lock-up," as many core reserves and buffer zones can accommodate a variety of human uses, so long as they are compatible with conservation objectives.

Our estimate of area needed in reserves is an order of magnitude beyond what is currently protected in most regions. We harbor no illusions about our vision being easy to accomplish. A smaller and better-educated human population is ultimately required. During the many years it will take to establish reserve networks of this scale, ways of managing land for human commodities and biodiversity may be improved. But because success in

TABLE 5.2. Factors That Influence Estimates of the Proportion of a Region That Must Be Protected in Reserves to Meet Conservation Goals

Factor	Type of influence
Size of region	The size of region considered will affect estimates of protected area needed. A small wild region containing communities not represented elsewhere may need to be protected entirely. Many regions are too small to maintain viable populations of carnivores without connection to other regions.
Heterogeneity	A highly heterogeneous region, with many habitats and associated species assemblages, will require more area to meet representation goals than will a more homogeneous region.
Classification	The system used to classify vegetation or other community types will determine the area needed to represent each type. Systems that recognize more types, or lower levels in a hierarchical classification, will lead to larger area estimates.
Replication	The number of sites in which a species or community type must be protected to meet representation goals will influence the total area required.
Unit size	The size of individual reserves in which a species or community is represented will influence estimates of total area required.
Area requirements	According to home range size and other aspects of autecology, species require different areas to maintain viable populations or metapopulations.
Population viability criteria	The length of time considered and specified probability of persistence will influence target population size and area required. Models with different assumptions or parameter values will lead to different estimates.
Habitat quality	Quality of habitat will, in part, determine population density of target species and therefore area required for persistence.
Human uses inside	Human activities inside reserves, for example livestock grazing or hunting, will affect habitat quality and survivorship of target species. If uses have a negative impact, larger areas will be required.
Human uses outside	Human activities outside reserves will determine amount of habitat needed in reserves. If multiple-use lands support populations of target species, reserve area may not need to be as large.
Natural disturbances	Regions with natural disturbance regimes characterized by large stand-replacing disturbances (e.g., northern Rocky Mountains conifer forests) will require more area in reserves than areas with small patch disturbances (e.g., eastern deciduous forest).
Connectivity	Connectivity of reserves and other suitable habitats, both within and among regions, will affect area estimates. If reserves are well connected, the total area needed in reserves may be smaller.
Human quality of life	People differ in their need for natural areas to provide a high quality of life. People with more tolerance for domesticated environments will be biased toward smaller area estimates for reserves.
Sustainability	The ability of a region to maintain optimally functioning ecosystems (in terms of services to human society) and be energetically self-sufficient depends on some high percentage of the region maintained as natural area (Odum and Odum 1972).
Politics	A desire to be politically reasonable or expedient will bias estimates of needed protection downward, often well below estimates based on biological criteria.

TABLE 5.3 Estimates of the Proportion of a Given Region Needed to Accomplish Conservation Goals

Region and authors	Goal	Proportion needed
Australian wetlands (Margules *et al.* 1988)	Represent each plant species at least once	4.6% of total number of wetlands, but 44.9% of total wetland area
	Represent all wetland types and all plant species at least once	75.3% of total wetland area
Islands in Gulf of California (Ryti 1992)	Represent all bird, mammal, reptile, and plant species at least once	99.7% of total area
Canyons (habitat islands) in San Diego County (Ryti 1992)	Represent all bird, mammal, and plant species at least once	62.5% of total area
State of Idaho (Scott *et al.* in press)	Represent all vertebrate species at least once	4.6% of total area[a]
	Represent all endangered, threatened, and candidate vertebrates and plants at least once	7.7% of total area
	Represent all 119 vegetation types at least once	8% of total area
Northern Rocky Mountains of United States (Metzgar and Bader 1992)	Maintain an effective population of 500 grizzly bears (actual population = 2000)	32 million acres, or roughly 60% of region
Southeastern United States (Noss 1991f)	Maintain an effective population of 500 Florida panthers (actual population = 1000–2000)	100–150 million acres, or roughly 60–70% of original range
Oregon Coast Range (Noss 1992c, 1993a)	Capture all clusters of rare species and community occurrences, protect all remaining primary forest, provide for large carnivore recovery	About 25% of region within each of two categories of reserves and an additional 25% in buffer zones
Average region in the United States (Noss 1992b)	Maintain viable populations of large carnivores and sustain natural disturbance regimes	Roughly 50% of region
Average region (A. Naess, cited in Sessions 1992)	Optimize human and nonhuman well-being	1/3 wilderness, 1/3 mixed communities of humans and other species, 1/3 intensive human use
State of Georgia (Odum 1970)	Optimize ecosystem services and human quality of life in self-sufficient system	40% natural, 10% urban–industrial, 30% food production, 20% fiber production
South Florida (Odum and Odum 1972)	Optimize ecosystem services and economic and cultural well-being	50% natural, 50% developed

[a]Area as represented by 389 equal-area hexagons of 635 km^2 each.

multiple-use management is uncertain, and because wild places are valuable for their own sake, the prudent course is to risk erring on the side of protection.

How Does Our Present Reserve System Compare?

According to the report *America's Biodiversity Strategy: Actions to Conserve Species and Habitats* (USDI–USDA, 1992), 10 percent of the land area in the United States is in "specially-protected areas"; 90 percent of this in national parks, wildlife refuges, wilderness areas, and wild and scenic rivers. The report claims that "[l]ittle or no development or human activity, other than controlled recreation, is allowed in these specially-protected areas,"—failing to mention that 35 percent of designated wilderness areas are open to livestock grazing (Reed *et al.* 1989); that national wildlife refuges are seriously threatened by livestock, logging, exotic species, trespassing, energy development, pollution, heavy sport hunting, and other incompatible activities; and that many national parks are overdeveloped by private concessionaires. The true figure for the proportion of land strictly protected in the United States is unknown, but is probably less than 3 percent.

Among the conspicuous oversights in the USDI–USDA report is the lack of any recognition of the inadequate size, connectivity, and buffering of existing reserves, or of their failure to represent ecosystem diversity. Sizes of existing reserves are far too small to meet most conservation objectives (Fig. 5.12). Research natural areas, designated for scientific and ecological values, are tiny—93 percent are smaller than 1000 ha (2500 acres), and the remaining 7 percent are smaller than 5000 ha (Noss 1990b). National parks are also dominated by small areas, with 55 percent of units smaller than 1000 ha (Schonewald-Cox 1983). Wilderness areas are somewhat larger, with most between 1000 and 100,000 ha, but only 12 percent are larger than 100,000 ha and only 1 percent larger than 1 million ha (Noss 1990b).

As of 1989, only about 1.8 percent of the lower 48 states was designated wilderness, or 4 percent of the United States including Alaska (Watkins 1989). Although the National Wilderness Preservation System has grown over the years, the amount of land that qualifies as wilderness in the United States has declined precipitously. In 1936 there were no designated wilderness areas, but an estimated 150 million acres of roadless lands in the lower 48 states qualified as wilderness. When the Wilderness Act was passed in 1964, 9.5 million acres were designated and 100 million acres of de facto wilderness remained. By 1985 the statutory wilderness system had grown to 32 million acres, but total wilderness (designated and de facto) totaled only 86 million acres (Wolke 1991). Wilderness is dwindling, not increasing.

Moreover, designated wilderness areas do a poor job of representing

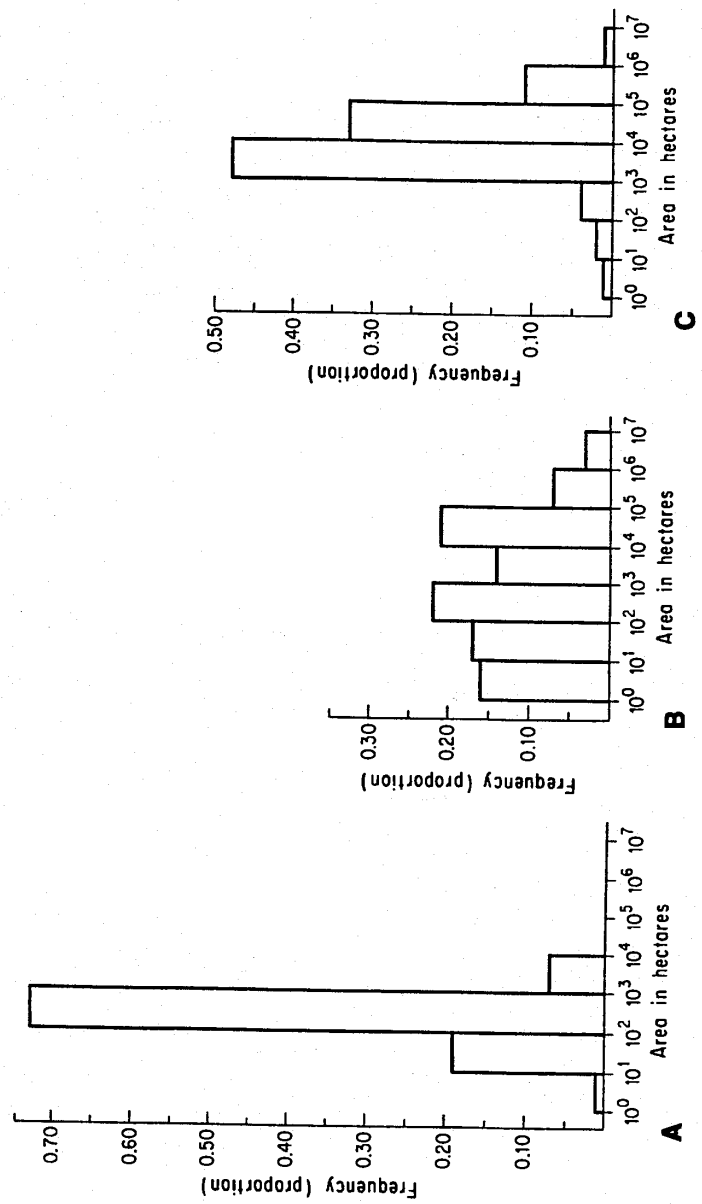


FIGURE 5.12 Size frequency distribution of (A) 213 Forest Service research natural areas; (B) 320 units in the national park system; and (C) 474 designated wilderness areas. From Noss (1990b).

ecosystem diversity. Many are truly rocks and ice (Forman and Wolke 1989, Wolke 1991). Davis (1988) found that 104 (40 percent) of 261 major terrestrial ecosystems in the United States and Puerto Rico (Bailey-Kuchler ecosystems; see Davis 1988, Noss 1990b) were not represented at all in wilderness areas. Applying a modest size criterion of 100,000 ha, only 50 (19 percent) of Bailey-Kuchler ecosystems were found in wilderness areas. East of the Rocky Mountains, only four ecosystem types are represented in wilderness areas in 100,000-ha units. Using a more ecologically reasonable size criterion of 1 million ha, which might be sufficient for short-term survival of large carnivores, only five (2 percent) of the 261 Bailey-Kuchler types were represented, all of them in Alaska (Noss 1990b).

The present system of protected areas in the United States is deficient. A major conservation priority is to use the criteria reviewed in Chapter 4 and in this chapter to expand dramatically the amount and quality of land protected throughout the nation.

Management Considerations

Establishing a reserve network is a necessary step toward maintaining biodiversity in a region, but it is not sufficient. The system of reserves, buffer zones, and linkages must then be managed. We discuss details of management for forests, rangelands, and aquatic ecosystems in forthcoming chapters. Here we offer only a few general comments.

Perhaps the key principle for managing landscapes for biodiversity is prudence: be cautious, move slowly, stay out of sensitive areas, avoid overmanipulation of habitats. Someday we may know more about how to manage land for all its values. For now we must concentrate on protecting the most sensitive components of the ecosystem. Prudence does not imply hands-off management in most cases. Indeed, much human labor will be required to protect a reserve from harm, to substitute for natural processes that have been disrupted, and to restore damaged habitats and recover populations. But we need to be careful.

In the case of the reserve system proposed for the Oregon Coast Range (see Chapter 4), management guidelines were offered for each of three land protection categories and for private lands outside the reserve network (Table 5.4). Similar guidelines would apply to other landscapes, particularly forested ones, where reserve networks are developed. The Coast Range strategy, like most regional case studies of The Wildlands Project, is a "100-year plan." Some elements of the strategy, such as carnivore reintroduction, might not be fully implemented for decades. But other actions are needed

TABLE 5.4 Protection, Management, and Restoration Guidelines for Three Categories of Land Protection and Undesignated Lands in the Oregan Coast Range[a]

Class I Reserves
No logging in primary forests of any age. No other timber cutting except thinnings and other silvicultural manipulations designed to restore plantations to natural structure and composition.
No new road construction or reconstruction.
Prompt closure of all roads, except major highways and other roads necessary to access private property or to conduct restoration activities. Obliterate and revegetate roadbeds. Reduce overall road density to well under 0.5 miles/square mile.
Limited trail systems and other access (follow typical wilderness area standards).
Initiate land acquisition programs to consolidate federal and state holdings by purchase of inholdings and other private lands. Some private lands can be protected by conservation easements and some may house reserve managers and researchers.
No grazing of domestic livestock.
No horses.
No mineral, oil, or gas exploration; no mining.
No collection of plants or other natural objects for commercial purposes.
Eliminate exotic (introduced) species, as feasible.
No control of native insects or diseases.
Fire suppression to be determined on a case by case basis, but generally discouraged (particularly after private inholdings have been purchased).
Reintroduce extirpated species (e.g., large carnivores) after road density sufficiently reduced, private lands or easements acquired, and feasibility studies suggest high probabilities for survival.
No off-road vehicles or other motorized equipment or mountain bikes.
Hunting permitted only as necessary to control herbivores.
Hiking, primitive camping, nature study, environmental education, and nonmanipulative research encouraged (manipulative research in the form of restoration experiments also encouraged on human-disturbed sites).
Class II Reserves
No logging in primary forests of any age. No other timber cutting except thinnings and other silvicultural manipulations designed to restore plantations to natural structure and composition or to accelerate development of old-growth characteristics in second growth.
No new road construction or reconstruction.
Prompt closure of unnecessary roads on public lands, with obliteration and revegetation of roadbeds. Gradual reduction of overall road density to no more than 0.5 miles/square mile.

[a] From Noss 1993a.

(Continued)

TABLE 5.4 (*Continued*)

Class II Reserves (*Continued*)
Trail system more extensive than in Class I Reserves, but limited enough to provide security to sensitive species.
Pursue acquisition of private lands or conservation easements, but can be more gradual than in Class I Reserves. In some cases, management agreements with landowners will suffice.
No off-road vehicles (except mountain bikes) or other motorized equipment on public lands.
No grazing of domestic livestock on public lands.
No mineral, oil, or gas exploration; no mining.
No collection of plants or other natural objects for commercial purposes.
Eliminate exotic (introduced) species, as feasible.
No control of native insects or diseases.
Fire suppression to be determined on a case by case basis, but generally discouraged (particularly after private inholdings have been purchased).
Reintroduce extirpated species (e.g., large carnivores) after road density sufficiently reduced, private lands or easements acquired, and feasibility studies conducted.
Hiking, horseback riding, mountain biking, legal hunting, primitive camping, nature study, environmental education, and nonmanipulative research encouraged (manipulative research in the form of restoration experiments also encouraged on human-disturbed sites).
Multiple-Use Buffer Zones
No logging in primary forests of any age. Timber management in plantations and some second growth permitted, but emphasizing long rotations, "New Forestry," selection logging, and other silvicultural systems that seek to simulate natural disturbance–recovery regimes. Restoration forestry and sustainable forestry experiments encouraged.
No new road construction or reconstruction.
Gradual reduction of overall road density to no more than 1.0 mile/square mile, except where higher densities are necessary to access private property.
Pursue conservation easements and management agreements with private landowners.
No motorized off-road vehicles on public lands.
Eliminate exotic (introduced) species, as feasible, on public lands.
Undesignated Lands
Practice sustainable resource production.
Protect riparian zones and other sensitive sites.

immediately. Otherwise, future conservation options will be limited. For the Coast Range, several priority conservation actions were proposed:

- A moratorium on logging of old growth and other virgin forests;
- A rapid phasing out of road construction, with existing roadless areas protected;
- Closure of unnecessary roads;
- A moratorium on development in all natural and near-natural habitats, instead channeling development into areas already manipulated or degraded;
- Initiation of restoration projects, both short-term and long-term; and
- Public education about what it takes to fully restore the richness of life in this remarkable region

These proposed short-term actions are not uncontroversial, but land managing agencies in the Coast Range region have shown a sincere interest in the plan. We feel that bold conservation plans will generally be taken seriously if they are scientifically defensible and have strong support from at least some local people. In the Coast Range, a regional group with several hundred members (the Coast Range Association) is vigorously advocating the plan and has gained support from other conservationists. It is too early to say that the Coast Range strategy or similar plans in other regions will be successful, but clearly the combination of science and citizen involvement can powerfully influence the future of a region. We hope to see this influence increase in all regions.