CHAPTER 5

Plants and Terrestrial Wildlife

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❄ CRITICAL FINDINGS

Plant Diversity Of California's 7,000 vascular plant species, about 50% occur in the Sierra Nevada. Of these, more than 400 species are found only in the Sierra Nevada, and 200 are rare.

Threats to Plant Diversity Three plant species marginally within the Sierra Nevada *(Monardella leucocephala, Mimulus whipplei,* and *Erigeron mariposanus)* appear to have become extinct in the last hundred years.

Vertebrate Diversity About 300 terrestrial vertebrate species (including mammals, birds, reptiles, and amphibians) use the Sierra Nevada as a significant part of their range, although more than 100 others include the Sierra Nevada as a minor part of more extensive ranges elsewhere.

Extinction Three modern vertebrate species once well distributed in the range are now extinct from the Sierra Nevada: Bell's vireo, California condor, and grizzly bear.

Vertebrate Species at Risk Sixty-nine species of terrestrial vertebrates (17% of the Sierra fauna) are considered at risk by state or federal agencies, which list them as endangered, threatened, of "special concern," or "sensitive."

Loss of Foothill Habitat Eighty-five terrestrial vertebrate species require west-slope foothill savanna, woodland, chaparral, or riparian habitats to retain population viability; 14% of these are considered at risk.

Loss of Riparian and Old-Growth Habitat The most important identified cause of the decline of Sierran vertebrates has been loss of habitat, especially foothill and riparian habitats and late successional forests.

Genetic Diversity Activities occurring in the Sierra Nevada that pose the greatest indirect and direct threats to genetic diversity are those that break the chain of natural selection and adaptation.

Genetic Management Genetic guidelines that alert managers to activities likely to have genetic consequences and inform managers about preferred management of seeds, plants, mushrooms, animals, insects, and other germ plasm have been mostly lacking, inadequate, or poorly implemented in land management of the Sierra.

Community Distribution Excluding marginal plant communities mainly distributed in the Mojave Desert and Great Basin, the Sierra Nevada encompasses eighty-eight plant community types as defined by California's Natural Heritage Division.

Private Ownership of Plant Communities Many of the foothill community types fall largely within private lands, notably grassland (88% of the mapped distribution on private lands), valley oak woodland (98%), blue oak woodland (89%), interior live oak woodland (71%), and foothill pine–oak woodland (82%).

Grazing Livestock grazing has been implicated in plant compositional and structural changes in foothill community types, meadows, and riparian systems, and grazing is the primary negative factor affecting the viability of native Sierran land bird populations.

Timber Harvest Six forest types are mostly found on lands available for firewood cutting or timber harvest, including interior live oak (81%), black oak (56%), east-side ponderosa pine (72%), Sierran mixed conifer (67%), Sierran white fir (62%), and lower cismontane mixed conifer–oak (70%).

Type Conversions Nearly 800,000 acres of oak woodlands in the Sierra Nevada have been converted to other land uses and vegetation types over the last forty years, a decline of almost 16%.

ASSESSMENTS

Sierra Nevada Plant Communities

The Sierra Nevada Ecosystem Project assessed all vegetated areas of the Sierra Nevada (15.6 million acres); 89.7% of the region is covered by plants (plate 5.1). The rest is rocky barrens, water, or settled lands. Eighty-eight natural plant community types have been described within the Sierra; about one-quarter of them have ranges of less than 6,000 acres. Conversely, twelve community types collectively contribute two-thirds of the region's total vegetated acreage (table 5.1).

Ownership and Management of Sierran Plant Communities

The SNEP assessment of terrestrial biodiversity focused mainly on the structure of commercial forest types, such as Sierran mixed conifer and red fir, and on the condition of selected rangeland communities, such as meadow and riparian types. Our findings are presented in more detail in chapters 23 and 58 of volume II. We did not systematically investigate the condition and trends of many of the region's ecosystems, but we did map the general distribution of all widespread plant communities, which we used as coarse surrogates for terrestrial ecosystems and wildlife habitats. We analyzed the distribution of each widespread type with respect to land

PLATE 5.1

Distribution of plant communities in the west-central Sierra Nevada. (From volume II, chapter 23.)

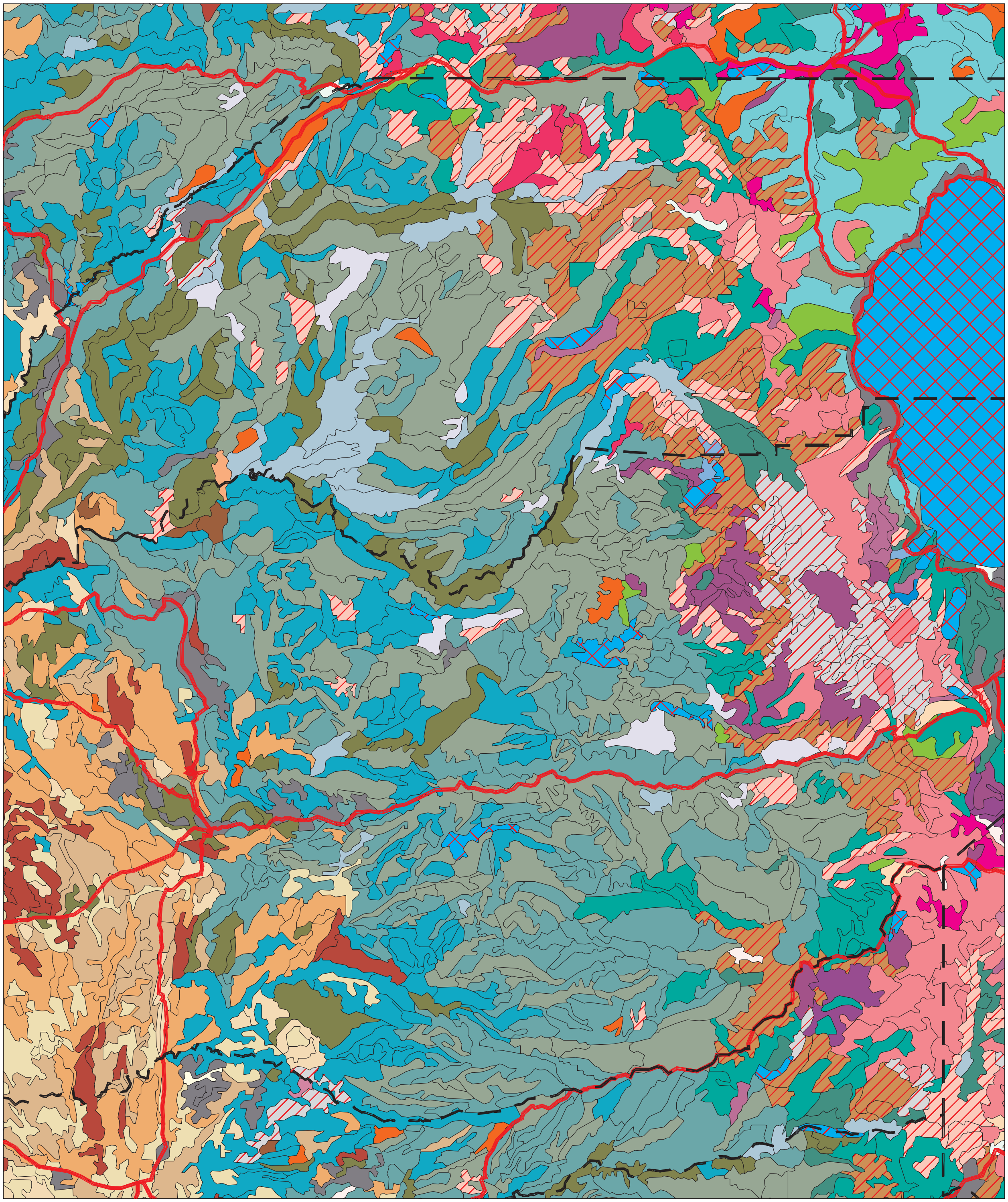

PLATE 5.1 continued

TABLE 5.1

Twelve major vegetation types of the Sierra Nevada.

Plant Community	Percentage of Total Vegetated Area in Sierra
Sierran mixed conifer forest	10
Blue oak woodland	10
West-side ponderosa pine forest	8
Lower montane mixed conifer–oak forest	7
Red fir forest	6
Foothill pine–oak woodland	5
Jeffrey pine–fir forest	5
Lodgepole pine forest	4
Jeffrey pine forest	3
East-side pine forest	3
Red fir, western white pine, and lodgepole pine–western white pine forest	3
Non-native annual grassland	3

ownership and management. Our objective was to identify types that might be especially vulnerable to land-use conversion or degradation because they are not well represented in existing designated conservation areas or are largely on land available for uses that could negatively impact native biodiversity. This map-based conservation risk-assessment method is known as *gap analysis* because it seeks to identify gaps in the representation of native biota in protected areas. Gap analysis is not a substitute for a detailed biological inventory, but it provides a useful description of regional vegetation patterns and helps to identify vulnerable plant communities and habitats. Our study was a collaboration with the National Biological Service's Gap Analysis Program (GAP).

The GAP uses land-management classes as a coarse measure for assessing the viability of plant communities. Communities that fall in lands allocated to certain extractive uses are likely to be more vulnerable than those in nature reserves, for example. Five ownership / management classes, based on fire policy and on potentials for development, timber harvest, and grazing were used for assessments:

Class 1: Public or private lands formally designated for conservation of native biodiversity. Development, grazing, and timber harvest are excluded. Examples include national parks, research natural areas, and Nature Conservancy preserves.

Class 2: National forest land that is generally managed for natural values but not formally designated for conservation. Development and grazing are excluded, and timber harvest is generally excluded.

Class 3: Public land that is generally managed for natural values, is currently classed as suitable for timber harvest, and may be grazed. Examples include grazing allotments in national forest wilderness, and Bureau of Land Management wilderness areas.

Class 4: Other public lands not included in Classes 1–3, mainly multiple-use lands.

Class 5: Private lands other than those in Class 1.

Use of these management classes as surrogates for biodiversity vulnerability is subject to many exceptions, and generalization is implicit. We do not intend to imply that timber harvest, grazing, or other activities are necessarily detrimental to biodiversity. Further, although the databases used in this analysis are the most comprehensive ever assembled for the region, producing the maps and analyzing the data at this scale require assumptions and simplifications, which need to be verified on the ground for local accuracy.

The GAP mapped 15% of the Sierra Nevada region as Class 1 lands. Yosemite, Sequoia, and Kings Canyon National Parks account for most (89%) of this area. These parks are an important source of large, continuous protected habitat. Nearly

❄ *Natural Diversity Database*

Plant community types are often used as a coarse descriptor of biotic and underlying environmental conditions. Since 1986, California's Natural Heritage Program has classified the state's plant communities into roughly 400 community types, using the Natural Diversity Data Base (NDDB) Plant Community Classification System (recently the California Native Plant Society has devised an alternative classification system that serves a similar purpose). To be consistent with the statewide gap analysis of California, SNEP employed the NDDB system. Excluding marginal communities mainly distributed in the Mojave Desert and the Great Basin, the Sierra Nevada encompasses eighty-eight plant community types.

The Heritage Program ranks each community type, much as species are ranked, to indicate its overall condition throughout its range in the state. Geographically restricted community types listed as very threatened by the Natural Heritage Division include Gabbroic northern mixed chaparral and Ione chaparral. More widespread Sierran community types listed as very threatened or threatened include sagebrush steppe, Sierra Tehachapi saltbrush scrub, big tree forest, west-side ponderosa pine forest, and east-side ponderosa pine forest. Types listed as threatened that are widespread in the Sierra Nevada but also have wide occurrence elsewhere include aspen forest, aspen riparian forest, black oak woodland, blue oak woodland, valley oak woodland, interior live oak woodland, serpentine foothill pine–chaparral woodland, wet or dry montane meadow, wet or dry subalpine meadow, and montane black cottonwood riparian forest.

half of the total units grouped as Class 1 lands, however, are small parcels, less than 100 acres, meaning that they may be unable to contribute to landscape-level ecosystem functions (migration, dispersal, metapopulation maintenance, animal habitat quality, recruitment). An additional 7% of the Sierra Nevada region is in Class 2 lands.

By adding the areas in Classes 3–5, we estimate that about 80% of the region, or 89% of the vegetated land, is available for grazing. Similarly, summing Classes 4–5, we find that about 57% of the land area is available for timber harvest.

The ownership of Sierran plant communities varies in a way that reflects the concentration of private lands at lower elevations and of National Park Service lands in the central and southern portions of the range. Many of the foothill plant community types fall largely within private lands, notably non-native grassland (88% of the mapped distribution on private lands), valley oak woodland (98%), blue oak woodland (89%), interior live oak woodland (71%), and foothill pine–oak woodland (82%).

A number of widespread community types occur disproportionately on national forest lands, notably low sagebrush scrub (79%), rabbitbrush scrub (93%), mountain mahogany woodland (94%), mixed montane chaparral and montane ceanothus chaparral (73%), bush chinquapin chaparral (85%), cismontane juniper woodland (86%), northern juniper woodland (85%), aspen (89%), east-side ponderosa pine (76%), Jeffrey pine forest (75%), Jeffrey pine–fir forest (80%), western white pine forest (75%), whitebark pine–lodgepole pine forest (86%), and alpine dwarf scrub (99%). Foxtail pine forest is the only type whose distribution falls mainly within the national parks (77%).

These results call attention to three conditions of special concern, and a fourth of relative security:

1. *Upland rangeland plant community types occupying more than 6,000 acres, with more than 90% mapped distribution potentially grazed.* Some 28% of Sierran plant communities are in this group and would be thus flagged for special concern about grazing management. Notable among these are black oak woodland, valley oak woodland, blue oak woodland, interior live oak woodland, and east-side ponderosa pine forest.

2. *Forest types occupying more than 6,000 acres, with less than 10% of their distribution in Class 1 areas.* Six widespread, lower-elevation Sierran forest types are largely available for timber harvest and are not well represented in Class 1 areas: interior live oak forest, black oak forest, east-side ponderosa pine forest, Sierran mixed conifer forest, Sierran white fir forest, and lower cismontane mixed conifer–oak forest.

3. *Chaparral types occupying more than 6,000 acres, with less than 10% of distribution in Class 1 areas.* The policy of suppressing wildfire and the widespread conversion of low-elevation chaparral to grasslands raise concern about the long-term sustainability of at least eight of these fire-adapted ecosystems.

4. *Community types that are well represented in Class 1 areas (more than 25% of their distribution is in Class 1).* Viewed Sierra-wide, thirteen types can be considered relatively low priority for additional land acquisition, administrative redesignation, or change in management in order to protect biodiversity. These include montane meadow, cismontane juniper woodlands, big tree (giant sequoia) forest, red fir–western white pine forest, red fir forest, lodgepole pine forest, whitebark pine–mountain hemlock forest, whitebark pine–lodgepole pine forest, foxtail pine forest, whitebark pine forest, Sierra Nevada fell field, and alpine dwarf scrub. All of these, of course, may be subject to local impacts that are not directly related to land classification, such as the spread of white pine blister rust, which disregards land-allocation boundaries.

Major differences exist in the representation of plant communities on the different land areas among regions of the Sierra. In general, the northern subregion is largely private or national forest land, and only 2.1% of this subregion is Class 1 land. These Class 1 areas are concentrated at higher elevations in the northern subregion. Potentially grazed lands (Classes 3–5) account for 88% of the area, while 71% is eligible for intensive timber harvest (Classes 4–5). Many types are almost wholly restricted to low-elevation private lands, including interior live oak (90%) and west-side ponderosa pine. Middle-elevation forests are more concentrated on the national forests (60%–90% on public lands). Because Yosemite, Sequoia, and Kings Canyon National Parks fall within the central and southern Sierra, the land-management profile of that subregion is strikingly different from that of the northern subregion. Class 1 areas and private areas are roughly equal in extent, covering 26% and 30% of the land, respectively. Roughly 75% of the area is available for grazing. The largest difference between the northern and the central-southern subregions lies in the management profiles of the major forest types. Virtually all of the community types possessing commercial forest species in the central-southern subregion have at least 20% of their areas in Class 1 lands.

Plant Species

Plants of the Sierra Nevada have provided food and shelter to humans for nearly 10,000 years and to wildlife for much longer. For more than a century the Sierran flora has attracted botanists from around the world; many of their names mark the scientific nomenclature of the species they described. Visions of giant sequoias, vast conifer forests, and open vistas of alpine tundra have added to the botanical allure of the range. Spanning nearly 300 miles from south to north and more than 14,000 feet in elevation, encompassing a wide range of soil and vegetation conditions and human land-use histories, the Sierra possesses a high diversity of plant species, and many species are endemic (restricted) to the range. Supporting more than 3,500 native vascular plants, the Sierra Nevada contains 50% of California's plant species, yet it comprises only 20% of the land base of the state. This species richness is greater than the total number of plant species growing in the entire state of Florida, which is considered the third most floristically diverse of the coterminous states.

Despite the attention of botanists, and perhaps because of the Sierra's diversity, floristic knowledge of the range is still so incomplete that species previously unrecorded in the Sierra, and new range extensions for those already known, are documented annually. For example, between 1968 and 1986, sixty-five new plants were described for the Sierra Nevada, and the trend continues. Studies of species viability and range expansions or contractions are exceedingly sparse. The nonvascular plants (lichens and mosses) are known even less. For these and other reasons, assessments of plants in the Sierra are highly provisional and concentrate mostly on entire plant communities, rare plants, and those with known conservation concerns.

About four hundred plant species occur only in the Sierra Nevada, including three trees, twenty shrub species, several hundred herbaceous plants, and at least two lichens and two mosses. Of this total, two hundred eighteen are considered rare or threatened by the California Native Plant Society or by state or federal agencies (figure 5.1). Within the Sierra, both genetic and species-level composition of Sierran plant community types change progressively from the southern to the northern end of the range. The plant species composition within any plant community type (for example, Sierran mixed conifer forest) changes systematically from north to south at a rate of roughly two plant species per mile. Consequently the Sierran mixed conifer flora of the far northern Sierra Nevada shares only half of its plant species with its southern counterpart. Of the geographic regions of the Sierra, the south is richest in species generally, as well as in numbers of rare species and species found only in the Sierra. The Owens River basin in the eastern Sierra is also an area of rarity and uniqueness for plant species.

Status of Rare Plants and Threatened Species

As a group, Sierran plants are most at risk where habitat has been reduced or substantially altered. Rare plants are scattered throughout the range in many different habitats and on both public and private lands. However, rare local geologic formations and their derived unique soils, such as the Ione Formation, have led to the evolution of ensembles of plant species restricted to these habitats. For most species, conservation status is a function of local land use, from past activities to future plans. Of the habitat types most frequently documented to contain rare and unique species, the foothill woodland and chaparral communities have been particularly altered and fragmented by changes in agriculture and settlement on the western slopes of the Sierra, including the introduction of Eurasian herbs and grasses and changes in the fire regimes required by many native plants. Timber harvest and fire suppression have altered the patchiness and complexity of conifer forests, degrading habitat for some plant species that rely on the natural forest mosaic, while stimulating habitat for other species. Overgrazing in mountain meadows is a threat to many rare species that are restricted to these habitats. Aside from land use that converts habitat (e.g., settlement), activities such as grazing, logging, mining, and recreation can be compatible with plant conservation as long as the ecology of rare species is taken into account. However, interactions among the timing, intensity, and frequency of these activities can well lead to cumulative adverse impacts on rare and common species and ultimately bring about the loss of entire populations if these impacts are not understood.

Sugar pine, a much-beloved tree and highly valuable timber species widely distributed in the Sierra, deserves note for the threat from a fatal non-native disease pathogen, white pine blister rust. This disease, native to Asia, was introduced accidentally to the United States via nursery stock early in the century and has spread throughout the range of native white (five-needle) pines. Sugar pine seedlings and young trees are killed outright, whereas older trees progressively lose portions of their crowns and may eventually die. The disease has spread in "wave years" when climate conditions are advantageous for the pathogen, and it is now widespread throughout sugar pine populations in the Sierra. A small proportion of sugar pines in most populations contains genetic resistance to the disease, and an active breeding and planting program has been developed from these resistant individuals. Resistance also provides a supply of sugar pines for natural regeneration that probably will survive the epidemic. Although sugar pine populations throughout the range are likely to experience severe declines in number as the epidemic spreads, the long-term prospects for this economically and ecologically important species in the Sierra are good, since natural resistance will be strongly selected for, and the efforts of the control program will provide supplements. Retention of large sugar pines, both resistant and not, throughout the range over the next half-century will play a critical role in maintaining the genetic diversity of the species and its ability to cope with new adversities.

White pine blister rust attacks other species of native white pines in the Sierra, and this may prove a far worse problem in the future than the attack on sugar pine. Although little research has been conducted, the other species do not appear to have native genetic resistance. In the Rocky Mountains, whitebark pine populations have suffered widespread die-offs in a remarkably short time, threatening a variety of wildlife species that depend on pine nuts. Should this situation occur in the Sierra, there would be little opportunity to apply the silvicultural techniques that have been used for sugar pine, since the other white pines exist in remote upper-elevation habitats and their silvic and genetic behaviors are little known.

Another group of species experiencing threat in the Sierra is lichens. Lichens have been used in air-quality monitoring

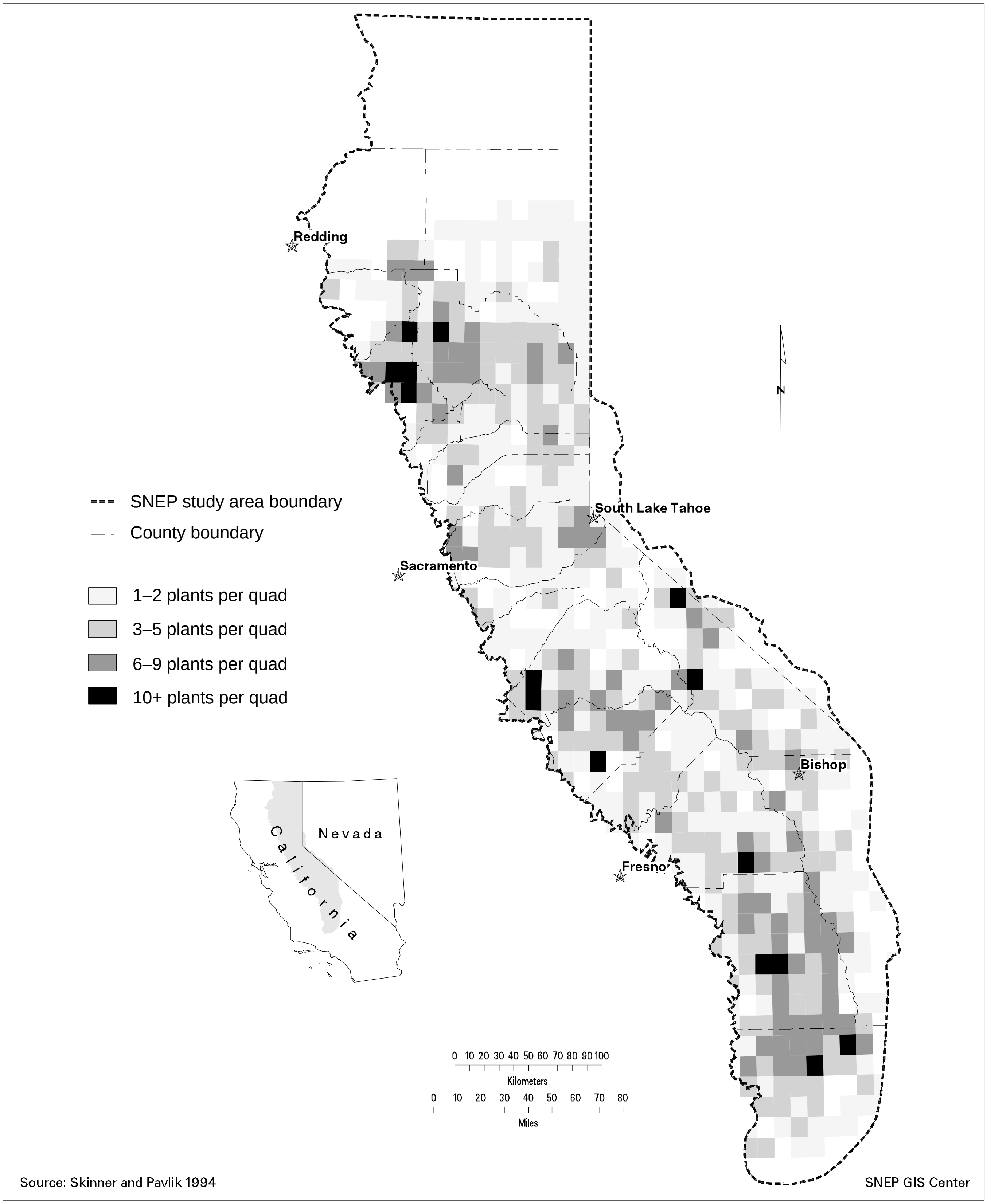

FIGURE 5.1

Distribution of rare plants by topographic quadrangle in the Sierra Nevada. (From volume II, chapter 24.)

studies because many species show physiological damage caused by air pollution. Air-quality degradation in the Sierra Nevada appears to be adversely affecting some lichens. Local extinctions of lichens are likely in the Sierra, similar to those that have occurred in southern California, if trends in air quality continue.

Terrestrial Vertebrate Species and Wildlife Habitats

Unlike plants, which generally stay in place long enough to be inventoried and mapped, animals move about, are often difficult to observe or capture, and vary naturally in population size from year to year. Hence, measuring populations, assessing geographic distributions, and assessing species and population viabilities are especially problematic for animals. Our assessments of the 400 species of terrestrial vertebrates that live in the Sierra Nevada depended upon a variety of published and direct sources, including databases from public agencies. For the vast majority of wildlife species, the quality and quantity of information on numbers and range are far below those necessary to make meaningful statements about status or distribution. The situation is even worse for trend data—monitoring over time. What little trend information exists is confined to such local sites that it seldom can be extrapolated to the entire Sierra. Ultimately, our most important source of information on viability of vertebrates at the scale of the Sierra Nevada was to infer distribution from habitat (mainly plant community information), using the California Wildlife Habitat Relationships (CWHR) computer database and model. Because animals depend on plant communities and their environments for habitat, they can be assessed indirectly by analyzing the status of those habitats. SNEP contributed to refining the portion of CWHR based on studies of species-habitat relationships in the Sierra Nevada to provide the most current available information. Although the information on the habitat requirements of many species is somewhat more complete than that for their population dynamics, unfortunately information on the distribution and quality of those habitat elements—riparian vegetation, large snags, montane meadows, vertical cliff faces, and myriad other factors that constitute viable habitat for a particular wildlife species—must presently be inferred from the gross vegetation types that represent most mapped habitat data.

Species Diversity

Of the four hundred species that use the Sierra to a greater or lesser extent, two hundred thirty-two are birds, one hundred twelve are mammals, thirty-two are reptiles, and twenty-five are amphibians (amphibians are treated at greater length in chapter 8 of this volume) (plate 5.2). However, only two hundred seventy-eight of these species use the Sierra as a principal part of their range and only thirteen are essentially restricted to the Sierra in California. During the Pleistocene, California's megafauna included camels, horses, giant ground sloths, mammoths, bison, and saber-toothed cats, all of which became extinct about 10,000 years ago. These animals largely occupied the valleys and coastal plains, but they undoubtedly lapped up into the foothills of the Sierra Nevada on both sides, although few remains have been found there. The causes for extinction of these large mammals are only surmised, but climate change and predation by early human arrivals are implicated.

At the time of European settlement of the area, large herds of tule elk and pronghorn were still present, especially in the interior valleys; mule deer dominated the foothills, and mountain sheep occupied the crest and eastern slopes. All four of these ungulates were hunted heavily by Spanish and other European settlers.

Modern Extinctions in the Sierra Nevada

Three modern species once well-distributed are now gone from the Sierra Nevada. These are the grizzly bear, least Bell's vireo, and California condor. Grizzly bears were well distributed in California at the time of Spanish settlement, recorded everywhere but the Great Basin, deserts, and eastern Modoc Plateau. In the Sierra they were reported most frequently in the foothill woodlands and chaparral, but they appear to have been distributed throughout the range. Spanish and later European settlers set out systematically to exterminate them. The last California grizzly bear identified with reasonable certainty was killed in Sequoia National Forest in August 1922. The closest known surviving grizzly populations are in northeastern Washington and the northern Rocky Mountains.

The least Bell's vireo was historically distributed widely in riparian habitat of the San Joaquin valley, southern Coast Range, and southwestern California, as well as the lower foothills of the Sierra Nevada. Small numbers of this species persist in southern California and along the California coast. The extinction of least Bell's vireo in the Sierra appears most likely related to nest parasitism by brown-headed cowbirds, although destruction of willow-dominated riparian corridors, which were fragmented by grazing, greatly reduced its habitat.

The last wild California condor was captured in Kern County in 1987, one of twenty-seven birds removed to captivity in an effort to save the species from extinction through captive breeding. The condor is a forager of open plains and savannas, where it once fed on the carcasses of Pleistocene megafauna and later the cattle and sheep that replaced them. In the twentieth century, it ranged widely if sparsely over the southern San Joaquin valley, southern coast ranges, and southern California. Condors selected nest sites in cliffs and even in giant sequoias, which brought them well into the west slope of the Sierra as far north as Tuolumne County. It is most likely that the decline of vast herds of Pleistocene ungulates made condors rare by the time of European exploration. Efforts to reintroduce California condors from the captive population are presently under way.

The factors that led to extinction of each of these animals

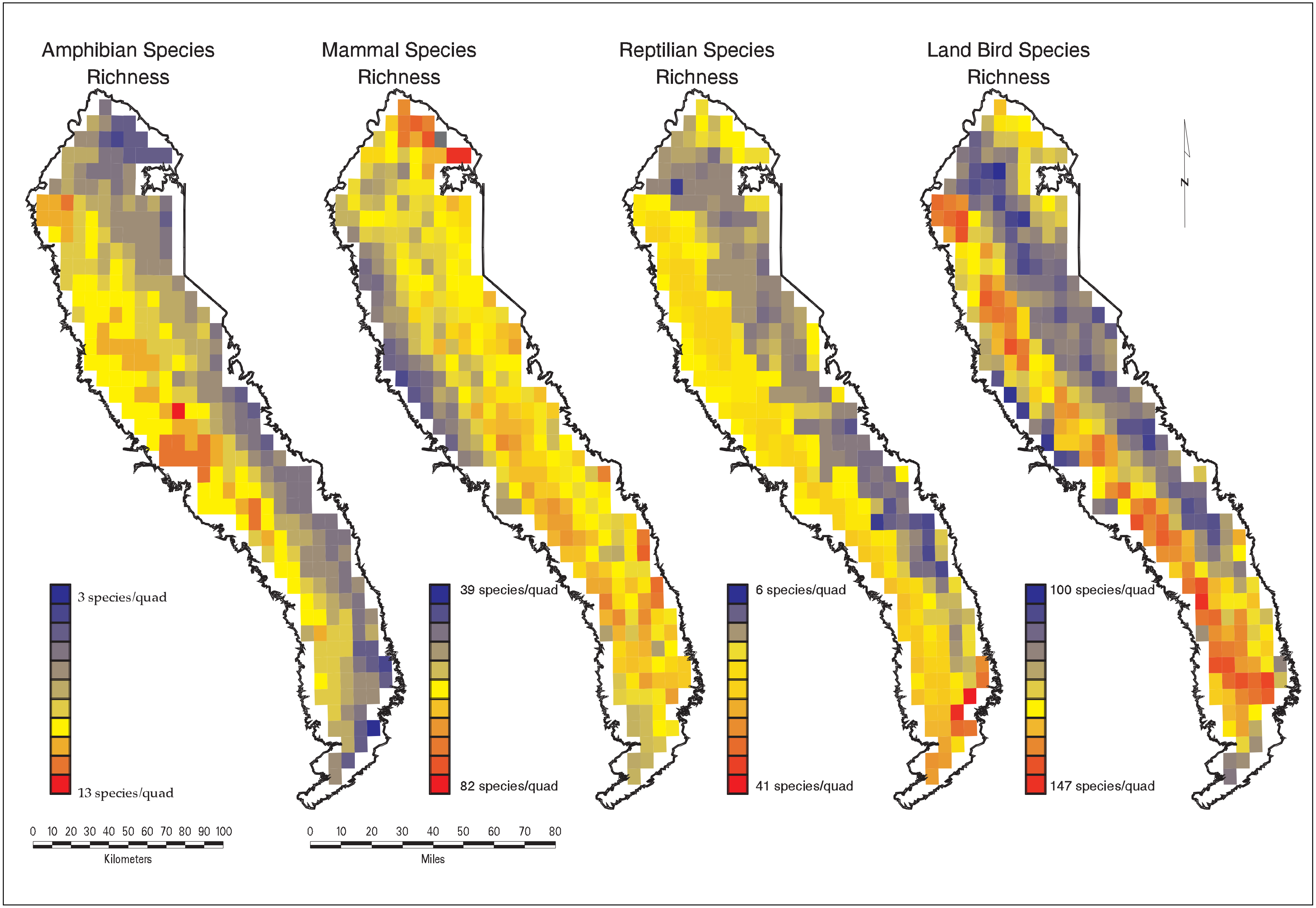

PLATE 5.2

Diversity (richness) of terrestrial vertebrate species in the Sierra Nevada: amphibians, mammals, reptiles, and birds. (From volume II, chapters 23 and 25.)

❄ *Terrestrial Vertebrates Restricted to the Sierra Nevada*

Thirteen vertebrates are essentially restricted to (live only in) the Sierra Nevada:

Amphibians: Yosemite toad, Kern County slender salamander, relictual slender salamander, Mount Lyell salamander, limestone salamander, Owens Valley web-toed salamander

Mammals: alpine chipmunk, long-eared chipmunk, Mount Lyell shrew, yellow-eared pocket-mouse, heather vole

Birds: pine grosbeak, white-tailed ptarmigan (non-native)

in the Sierra were different: For grizzly bears, it was direct, intentional extirpation by killing; for least Bell's vireos, it was habitat disturbance, both directly and indirectly through modifications that encouraged the spread of the brown-headed cowbird into vireo habitat; and for California condors, it was climate change and the arrival of humans to the New World, which led to the demise of the condor's prey, although the coup de grâce appears to have come from modern phenomena, such as condor ingestion of lead slugs in game carcasses and contact with power lines. Because all three species exist elsewhere, should society wish to do so and bear the costs, all three could be reintroduced to the Sierra Nevada.

Non-Native (Alien) Species and Their Effects

Fifteen terrestrial vertebrate species now well established in the Sierra are not native to the region. Several of these have had significant detrimental impacts on the ecology of the Sierra Nevada and its native species. The most serious effects have been produced by the brown-headed cowbird, which was self-introduced early in the century. The spread of this nest-parasitizing bird in the Sierra (and the West in general) has mirrored the spread of farmland, livestock grazing, clear-cut logging, and suburban development. Cowbirds are implicated in or directly charged with the decline of several songbirds in the Sierra Nevada, especially the willow flycatcher, least Bell's vireo, yellow warbler, chipping sparrow, and song sparrow. Many songbirds beyond these are susceptible, although the effects of parasitism can be highly local. Parasitism rates (proportion of native species' eggs replaced by cowbirds' eggs in a nest) in excess of 10% are cause for concern, and those over 30% are a serious problem.

Cowbirds were first reported in the western Sierra foothills in 1915 and at Mono Lake in 1916. The species is now widespread throughout the lower and middle elevations of the Sierra. Cowbirds travel as far as three miles from feeding sites to host nests. Preferred foraging areas for cowbirds in the Sierra include heavily grazed meadows, recent clear-cuts (especially those that are grazed), open forest with short grass understory, pack stations and stables, picnic areas and campgrounds, lawns and golf courses, and residential areas with bird feeders. Closed-canopy and multilayered forests, forests with shrub understory, tall grass meadows, and clear-cuts after shrubs and trees are established do not provide cowbird feeding habitat, but these areas can be parasitized if they lie within a three-mile radius of feeding habitat.

Several other non-native species have significant locally negative effects on native species. European starlings and house sparrows compete aggressively for nest sites with several native Sierran bird species, and starlings particularly may reduce the nesting success of native cavity nesters. These aliens are abundant in the Sierran foothills in and adjacent to urban and agricultural lands. Bullfrogs, native to the eastern United States, have completely replaced Sierran native red-legged frogs and foothill yellow-legged frogs in many locations. Bullfrogs also prey on western pond turtles and other aquatic and riparian wildlife species. Wild pigs are increasing in the Sierra foothills, where they compete for forage with native species, destroy herbaceous vegetation, and root extensively.

Changes in Sierran Habitats and Habitat Dependency

The extreme and systematic alteration of several life zones in the Sierra has had significant impacts on terrestrial vertebrates. Some impacts are likely irreversible; others are on a threshold trending toward this condition. Oak savannas, oak woodlands, and foothill chaparral on the west slopes of the Sierra have been extensively modified. The herbaceous understory in these communities was virtually replaced by introduced Eurasian grasses and herbs (dicots) in the mid-ninteenth century. Most of these areas have been grazed heavily for many years or converted to agriculture; some former chaparral has been converted to grazing land, and much of the rest has grown decadent or succeeded to conifer forest, owing to the suppression of fires. Local firewood collection has reduced the abundance of large old trees, snags, and fallen logs. These foothill communities have been extensively settled. Historically the habitats were extremely important to many birds and mammals that wintered at lower elevations where winters are mild and production of food remains high enough to support them.

Riparian habitats, those areas associated with streams, lakeshores, and other wetlands, have similarly suffered proportionately greater reduction through human modification than many other Sierran habitats. These habitats are critical to many Sierran species, not only because of the availability of water itself in a region with six months of drought but also because of their milder temperatures during the summer, higher production of food, hiding cover, insect prey, variety of nest sites, and opportunities for migration and local movement along the east-west riparian corridor. Losses have occurred through water diversions, the drowning of bottomlands by reservoirs, long-term grazing in riparian zones, timber harvest, and settlement.

Conifer forest habitats in general have been less extensively and less severely modified than foothills and riparian communities. Timber harvest, combined with fire suppression, has modified important animal habitat elements: tree size, tree density, and the presence of large logs and snags in west-side and east-side pine, mixed conifer, and red fir forests. Widespread simplification of forest structure, especially loss of the natural forest mosaic, and the reduction of late successional forest areas through harvest have adversely affected species that use these habitats.

In the Sierra, eighty-three terrestrial vertebrate species are considered to be dependent on riparian habitat to sustain viable populations; 24% of these are listed as species "at risk" (see the next section). Seventeen species are similarly dependent on late successional foothill savannah, woodland, chaparral, or riparian habitat (some are double-counted with species requiring riparian habitat) for Sierran population viability; 16% of these species are at risk. This last number is misleadingly low because many species at risk in the Sierra are more widely distributed elsewhere, such as in the Coast Range.

Status of Sierran Terrestrial Vertebrates at Risk

Species considered at risk in the Sierra, because they are listed by state or federal governments as endangered or threatened, listed by California as being of "special concern," or listed by federal land managers as "sensitive," include thirty-three birds, nineteen mammals, four reptiles, and thirteen amphibians; these constitute 17% of the Sierran terrestrial fauna. For California as a whole, about 30% of the fauna are so listed. Thus, based on this administrative criterion alone, Sierran terrestrial vertebrates are nearly twice as secure under present conditions as is the full state fauna. When other information is brought to bear, however, a rather more complex picture emerges. A brief summary by groups follows.

Mammals. The one hundred twelve species of mammals that regularly use the Sierra Nevada are dominated in number by the smallest of them, including seven shrews, seventeen bats, seven rabbits, and fifty-six rodents. Most of these are nocturnal and seldom seen. Bat numbers seem to be declining in recent decades, perhaps because of use of pesticides, loss of the large old trees and snags associated with late successional conifer forests, and loss of riparian habitats.

Of the larger mammals, including the forest carnivores red fox, fisher, marten, and wolverine, marten continue to occupy their historic range in the Sierra Nevada; fisher populations appear to be persisting in the south but are largely gone from their former ranges north of Yosemite National Park. The decline of fisher is associated with (among other causes) heavy trapping and changes in the structure of their habitat due to timber harvest and other activities that use resources. Red fox and wolverine have been so little studied that changes in their status cannot be determined.

Mountain sheep, once ranging the high Sierra south of Sonora Pass, were decimated by hunting, severe overgrazing by domestic sheep, and transmission of respiratory bacteria from domestic sheep following the arrival of Europeans in the mid-nineteenth century. Bighorn sheep were reintroduced in several locations in the southern Sierra (figure 5.2). Populations increased steadily until the early 1990s, when multiple causes seriously reduced herds. The current total Sierran population is well below the 250 recorded when reintroductions began in 1979, leaving the prospect of secure reestablishment in the wild distinctly pessimistic. A captive breeding program recently has been proposed as an emergency stopgap measure.

Birds. Of all the vertebrate groups in the Sierra Nevada, breeding land birds are the best monitored. The Breeding Bird

FIGURE 5.2

By the 1970s, Sierra Nevada bighorn sheep, which had once widely populated the crest of the range, were reduced to two populations totaling about 250 individuals. Beginning in the late 1970s, individuals such as this one from the large Baxter Mountain herd (Kings Canyon National Park/Inyo National Forest) were introduced into former Sierran habitats. By 1990, there were five bighorn sheep herds in the central and southern Sierra Nevada. Unfortunately, since that time, probably because of weather, mountain lion predation, and other factors, the herds—including the Baxter Mountain herd—are greatly reduced in numbers and have been at risk of extirpation. (Photo by David Graber.)

Survey (BBS) has maintained systematic monitoring over seventeen routes in the entire Sierra Nevada since 1966. The data collected indicate species that are likely in decline (table 5.2) and species probably increasing (table 5.3). Although this monitoring is more robust than that done for any other group of vertebrates Sierra-wide, it fails to detect birds in adequate numbers, and thus fails to assess trends, when bird species are already uncommon or when too few of the seventeen monitored routes (transects) intersect the appropriate habitat of a species. Ironically, as a result, many species that are on state or federal risk lists are not shown on the BBS; examples include the black swift, purple martin, and yellow-breasted chat. Moreover, raptors and waterbirds are not monitored by the BBS. Populations of listed birds, including the raptors (e.g., prairie falcon, osprey, long-eared owl, and spotted owl) and waterbirds (e.g., harlequin duck, Barrow's goldeneye), are often monitored at local levels, but rangewide trends are largely unavailable.

A review of the birds in tables 5.2 and 5.3 shows that neotropical migrant birds (i.e., those that migrate to the tropics after breeding) in the Sierra, despite their reported vulnerability, do not seem to be faring worse than other species. By contrast, short-distance migrants (e.g., the red-breasted sapsucker and white-crowned sparrow, which winter in the foothills and valleys) seem, as a group, to be doing most poorly in the Sierra. This is not to say that individual neotropical migrant species might not be declining or that tropical deforestation is not a problem for Sierran land birds, but merely that any generalizations about massive declines in neotropical land birds in the Sierra may be unfounded.

Among the potential risks faced by Sierran land birds, grazing and its secondary effects appear to be the single most significant negative factor. Montane meadows and montane riparian habitats are extremely important for Sierran birds; by midsummer, montane meadows may be the single most critical Sierran habitat requirement for many species that do not use this habitat during the actual breeding season. Grazing catalyzes changes in meadow plant species and cover, with cascading effects on birds. Changes in herbaceous and shrubby growth in meadows potentially alter the levels of prey insects, change use patterns by predatory birds, alter nest-building opportunities, and change the water relations of meadows, which sometimes leads ultimately to loss of meadow area. Nest parasitism by non-native cowbirds may be increased by grazing, although grazing itself is not as important to the spread of cowbirds as are agricultural practices and feedlot distribution in the regions adjacent to the Sierra. Local cowbird-control programs related to grazing practices and aimed at certain critical meadows and riparian habitats may be necessary to protect remnant populations of some rare Sierran birds and already show promise where they have been tried. In recent decades cowbird populations on the Sierran transects have been declining, perhaps from reductions in grazing and logging disturbances where those transects occur. However, cowbird populations are still plentiful and widely distributed in the Sierra Nevada, and anecdotal reports suggest they may be occupying higher elevations than they previously did.

Forest management practices, particularly logging and fire suppression, can have a profound effect on land bird populations in the Sierra. Large clear-cut blocks (not widely found in the Sierra) entirely remove forest habitat. Even-aged forests and forests with a structural diversity that has been simplified both spatially and vertically (loss of crown layers, snags, multiple-aged trees, diverse understory layers, coarse woody debris) by selective logging and fire suppression also result in decreased habitat for many forest species. In addition to complex forest structure, large trees and snags are especially important for land birds. Beyond increasing the potential for large, severe wildfires that destroy large blocks of habitat, fire suppression has led to forest and chaparral conditions inimical to many Sierran land birds, conditions in which highly localized habitat elements have been lost.

Pressure for increased development throughout the Sierra, but especially in the foothills and lower elevations of the west slope, is an increasingly significant threat to Sierran land birds.

TABLE 5.2

Breeding land birds in potential decline in the Sierra Nevada. (Data from the Breeding Bird Survey, 1966–91; table from volume II, chapter 25.)

Species Decreasing[a]	Mean Annual Trend (Percentage)	Species Likely Decreasing[b]	Mean Annual Trend (Percentage)
Band-tailed pigeon	–5.5	Mourning dove	–1.8
American robin	–2.7	Mountain chickadee	–1.2
Red-breasted sapsucker	–7.5	Dark-eyed junco	–2.7
Chipping sparrow	–5.0	Belted kingfisher	–7.6
Olive-sided flycatcher	–3.2	Golden-crowned kinglet	–3.3
White-crowned sparrow	–9.7	Brown-headed cowbird	–2.3
		Western wood peewee	–2.0
		Swainson's thrush	–2.6
		House finch	–8.5
		Steller's jay	–2.1
		Black-headed grosbeak	–1.7
		Lesser goldfinch	–4.0

[a]P<0.05 or <0.01 depending on number of transects.
[b]0.01<P<0.10 depending on number of transects.

TABLE 5.3

Land birds likely increasing in the Sierra Nevada. (Data from the Breeding Bird Survey, 1966–91; table from volume II, chapter 25.)

Species Increasing[a]	Mean Annual Trend (Percentage)
White-headed woodpecker	+3.4
Cliff swallow	+26.3
Hammond's flycatcher	+4.9
Common raven	+9.1
Fox sparrow	+3.2
Black phoebe	+3.9
House wren	+2.4
Solitary vireo	+5.5
Warbling vireo	+1.8
Yellow warbler	+3.1
Yellow-rumped warbler	+3.0
MacGillivray's warbler	+1.7

[a] $0.01<P<0.10$, depending on number of transects.

Woody riparian habitat, oak woodland, and chaparral are most affected. Many, perhaps most, Sierran species that specialize in oak woodland habitats seem to be decreasing in the Sierra. Because most of the original riparian habitat of the Central Valley is gone, the remaining habitat in the Sierra becomes all the more critical. Although loss of habitat is the most serious impact of human settlement, even low-density development produces a host of subtle but significant problems.

Reptiles. Of thirty-two native species of reptiles, four are considered at risk: western pond turtle, blunt-nosed leopard lizard, California horned lizard, and California legless lizard. All these species are found elsewhere, and, with the exception of western pond turtle, only marginally lap into the western Sierran foothills. Habitat alteration as a result of agriculture and development in the Central Valley and other parts of these species' ranges seems to be the primary cause of decline. For the remaining reptiles, especially the few that are truly montane, such as western rattlesnake and western terrestrial garter snake, little organized information exists and assessments are largely anecdotal.

Genetic Diversity

Genes are the fundamental unit of biodiversity, the raw material for evolution, and the source of the enormous variety of plants, animals, communities, and ecosystems that we seek to conserve and use in the Sierra Nevada. Genetic variation shapes and defines individuals, populations, subspecies, and ultimately all plant, animal, fungal, and bacterial life on earth. The gene pool (collection of all genes within a species) of a widespread species such as ponderosa pine consists of many populations; of a rare species, it may be only a single population. From one species to the next, the composition and structure of individual gene pools varies. Some species of plants and animals consist of populations each locally adapted to its environment, while other species appear to be generalists, possessing relatively low overall diversity or showing genetic diversity mostly among individuals rather than among populations. Forces of natural selection and history shape gene pools in the continuous process of short-term adaptation and long-term evolutionary change. The composition and structure of the gene pool, as shaped by natural selection, has a unique relationship to viability and long-term survival of populations and ultimately each species.

Many human actions on the landscape have some genetic effect. While certain changes in genetic diversity occur naturally, some human activities in the Sierra Nevada accelerate or alter the direction of evolution in undesired ways. Gradual or rapid loss of genetic diversity (genetic erosion), introduction of ill-adapted genes (genetic contamination), and major shifts in gene pool structure are changes that have been brought about by human actions in the Sierra. With direct information on genetic diversity virtually nonexistent for all taxa except a few well-studied trees, fish, and scattered plants and animals, we are left to make indirect inferences about the potential effects of past human actions on gene pools and the future consequences of those effects.

In the Sierra, any human activity that breaks the chain of natural selection, or forces rapid changes in adaptation on populations, is potentially detrimental to gene pools in both the short and the long term. Such effects include habitat alteration (habitat destruction, degradation, and/or fragmentation); silviculture (tree harvest, seedling culture, and planting methods); severe wildfire (artificially large and stand-replacing fires); ecological restoration (planting); fish management (hatchery culture, fish stocking); range habitat management (shrub planting); and accidental introduction of non-native pathogens. While genetically aware programs exist for managing tree stock (tree planting) that likely mitigate most potentially detrimental effects to forests, attention to genetic consequences is mostly lacking in other forest- and range-management activities. Introduction of salmonid fish to Sierran waterways, in addition to its cascading effects on invertebrates and amphibians, has resulted in hybridization with native trout and led to the loss of local distinctiveness of most native Sierran stocks, as well as threatening the very existence of some species, such as the Little Kern golden trout, through genetic swamping. Transmission of disease pathogens from domestic sheep to native bighorn sheep has caused high mortality in the latter species, which had evolved with little resistance to Eurasian diseases. This has probably caused severe losses of genetic diversity in the small populations, as well as the more obvious immediate effect of population extinctions. Direct knowledge of genetic diversity and its implications for adaptation will likely never be well known for most Sierran taxa. In light of this, however, preventive actions can be taken and genetic guidelines followed in many forms of management to mimic natural selection and the evolutionary process in preserving as much genetic diversity as possible.

MANAGEMENT STRATEGY

Biodiversity Management Areas

As summarized in the previous sections, human activities are exerting significant impacts on native Sierran plant and animal biodiversity. In addition to outright habitat conversion to residential or agricultural use, impacts accompany extractive activities such as grazing and timber harvest. The effects of these activities, however, depend on their timing, duration, and intensity. It appears that many native species are compatible with renewable uses, given appropriate management practices. On the other hand, SNEP's gap analysis indicates that many Sierran plant community types, which are crude surrogates for total biodiversity, are not well represented in areas where maintenance or restoration of native biodiversity is the primary management emphasis. As a result, some environments and species are more vulnerable to conflicting land uses than others, and there is very uneven knowledge of status and trends among community types.

One strategy that could contribute to conservation of Sierran biodiversity would be to improve the representation of plant community types in areas whose primary management foci are restoration and maintenance of native biodiversity. Design and implementation of a system of such areas would likely require a large investment of land and financial resources. Many questions would need to be addressed before committing to such a system. Which environments and community types are most vulnerable and in need of additional representation? How much area is required to meet specific conservation goals? Where should new Biodiversity Management Areas (BMAs) be located? Can representation of biodiversity be achieved using only public lands? How well could such areas address other concerns raised by SNEP related to forest structure, aquatic biodiversity, and areas of special ecological interest?

Goals

The following pertain to all strategies using BMA methods:

1. Represent all plant community types, as defined by the state of California Natural Heritage Division, in a regionally designed set of BMAs whose main objective would be restoring and / or maintaining native biodiversity.

2. Locate the BMAs as efficiently as possible in terms of both size and suitability of the area selected to meet a specified target for representation.

Possible Solutions

BMAs can be defined as specially designated public or private lands with an active ecosystem management plan in operation whose purpose is to contribute to regional maintenance of native genetic, species population, and community levels of biodiversity and the processes that maintain biodiversity. Each BMA is part of a regional system of BMAs and is located and managed to minimize the total risk to regional biodiversity. A BMA may target specific organisms or community types for restoration and management but not to the exclusion of other components of local biodiversity. Management may include programs to test and refine best management practices for extracting renewable natural resources. Economic activities are not necessarily precluded, but they are subordinate to the goal of maintaining native biodiversity.

The system of BMAs is designed to be representative of biodiversity but is not intended as a comprehensive reserve strategy that in itself can guarantee the viability of the native biodiversity of the Sierra Nevada. The SNEP BMA strategy assumes that the region will remain largely rural in character and managed for renewable resources in a way that sustains many if not most elements of native biodiversity. Given this scenario, a BMA system could not only provide sanctuaries for some species least compatible with human activities in the region but also provide a kind of insurance policy for maintaining native species and ecosystems. It is then largely a societal decision how much land to allocate to BMA status.

Designing a BMA system requires definition of a planning region, a starting set of BMAs, a set of sites within the region from which to select new BMAs, target levels for representing plant communities in BMAs, a means of comparing the suitability of different sites for BMA status, and a means of comparing the desirability of alternative BMA systems that all meet the stated goal for representing biodiversity.

SNEP developed and tested a computer siting model to explore opportunities for a comprehensive BMA system for the Sierra, in the following manner:

❄ *SNEP Significant Areas Inventory*

In addition to specific inventories of features such as old-growth forests and wildlife, SNEP mapped 945 areas of special interest on the national forests and national parks of the Sierra Nevada (figure 5.3). These areas contain features of special ecological, cultural, or geological diversity. A feature was considered significant if it was unusually rare, diverse, or representative of natural (including cultural) diversity. The average size of the areas was 3,349 acres for ecological features, 5,804 acres for cultural features, and 9,443 acres for geological features. More than 70% of the areas were newly recognized. Although more than a third of these areas are in "protected" categories of land designation (wilderness, natural reserves, parks, etc.), more than half were recorded as having had past or continuing impacts from intensive human uses, including recreation and grazing.

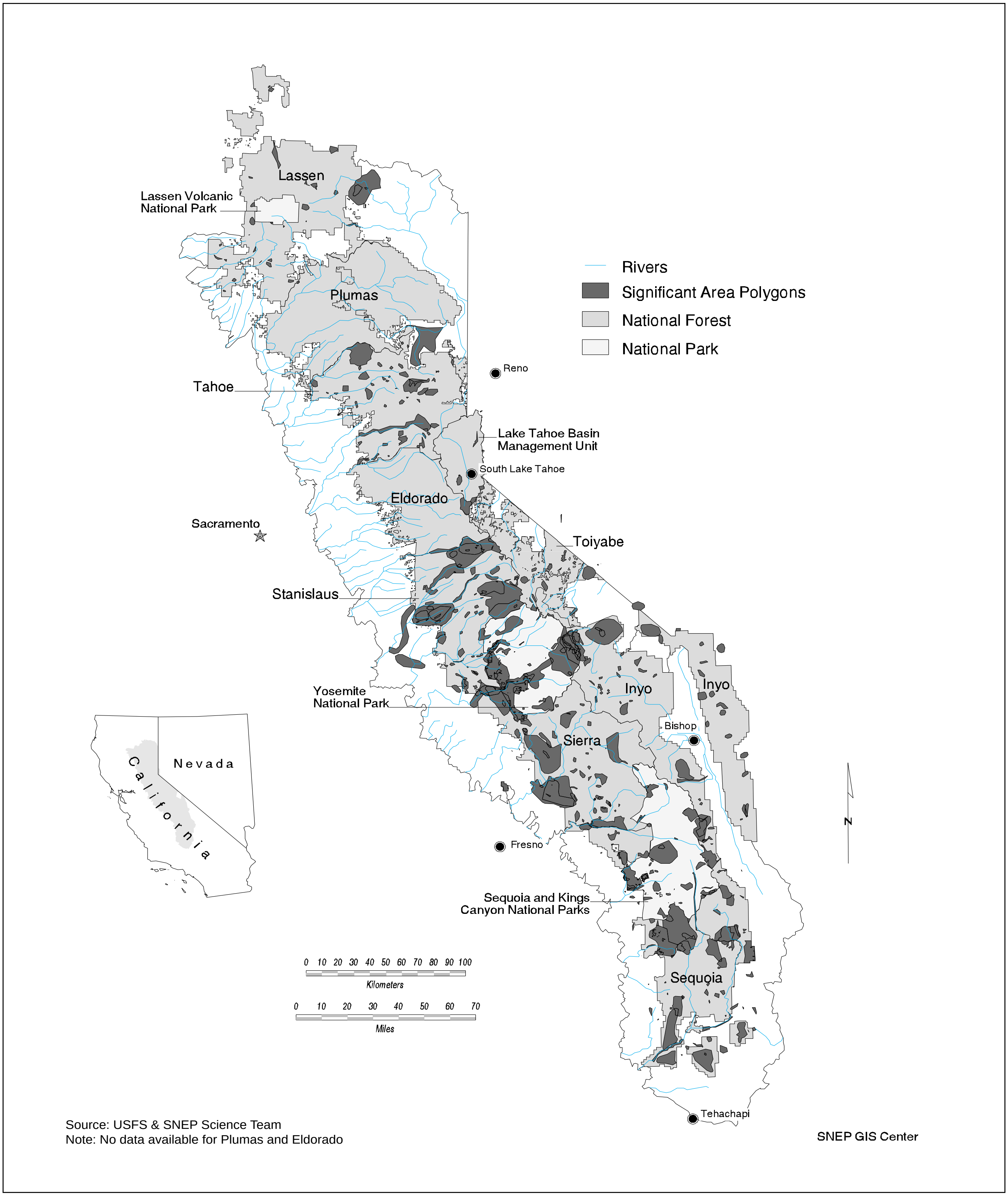

FIGURE 5.3

Ecologically significant areas mapped by SNEP. (From volume II, chapter 29.)

- The range was divided into northern, central, and southern regions.
- Each region was divided into planning watersheds averaging 7,500 acres in size. These watersheds form the set of sites for selecting new BMAs. (Only entire watersheds were selected.)
- A watershed suitability index was devised based on human population density, road density, the proportion of the watershed in private lands, and the degree of intermingling of public and private lands.
- Several starting BMA systems were compared. For example, one alternative assumed no existing BMAs. Another considered all parks, designated nature reserves, and ungrazed designated wilderness areas as BMA lands.
- We compared two target levels for representing plant community types in BMAs: 10% versus 25% of the distribution of each plant community type as mapped in the GAP database.
- The best (optimal) BMA system was the set of sites that required the least total area to meet the representation target and also had the highest total suitability. (In practice there is a trade-off between reducing the area required and maximizing the suitability of the solution.)

This strategy is not directed at a specific ecosystem problem. Instead, it is formulated as a proactive conservation approach to reduce the vulnerability of Sierran biodiversity to conflicting land uses—and to do so efficiently. The specific ecological concerns and management responses would vary among the different BMAs, which would be located to represent the full array of Sierran plant community types. SNEP addressed five specific questions related to the likely scope of a BMA system, depending on different assumptions and priorities.

1. ***What is the minimum area required to represent all Sierran plant community types in BMAs? How does a representative BMA system compare to the existing set of parks, wilderness areas, and reserves in the region?***

If one ignores current land ownership and management designations and sets out to represent plant communities proportionately in a BMA system based on watersheds whose average size is 7,500 acres, an efficient BMA system requires land in direct proportion to the target level, at least over the range of target levels examined in this study. In other words, it takes roughly 10% of the region to meet a 10% goal, and 25% of the region to meet a 25% goal. The pattern of selected watersheds is very different from the current distribution of parks and wilderness areas, which are concentrated at middle and high elevations in the central and southern portion of the range.

In the northern Sierra, if one starts with a BMA system composed of Class 1 lands as defined by the Gap Analysis Project (see "Ownership and Management of Sierran Plant Communities" earlier in this chapter), only five of fifty-nine plant community types exceed a 10% target level. At a minimum, a representative BMA system to meet this target level would require roughly 500,000 acres to include all plant community types. This is an area roughly two-thirds the size of Yosemite National Park.

In the central and southern Sierra, Yosemite, Sequoia, and Kings Canyon National Parks, despite their large size, do not encompass the full suite of plant community types. Roughly half of the native plant community types in these regions do not meet or exceed a 10% target. Meeting that target would require a minimum of roughly 370,000 acres of additional BMA land, 30% of which is currently privately owned.

Increasing the size of the BMA units by a factor of three, from "planning watersheds" to "superplanning watersheds" (approximately 22,500 acres) has a surprisingly large effect on the distribution and areal efficiency of the solution, increasing the area required to reach a 10% target by 27%. This illustrates both the sensitivity of the model results to the choice of planning sites and the trade-off between increased BMA size and decreased efficiency for representing regionally dispersed elements of biodiversity. However, the preservation of many elements of biodiversity (such as large animals) and processes (such as fire) requires units at least as large as superplanning watersheds.

2. ***How does the location of BMAs relate to the distribution of areas of special interest that have been identified in other SNEP assessments and scenarios?***

Solutions using the BMA model show only a modest degree of overlap with other SNEP biodiversity strategies, unless the model weighting factors are adjusted to favor those areas (e.g., Aquatic Diversity Management Areas and Areas of Late Successional Emphasis). Overlap is slight because the latter designations are predominantly located on public lands, whereas many plant communities can be adequately represented only if private lands are included in the solution. However, BMAs can be selected that not only aim to preserve biodiveristy but also favor other SNEP areas of emphasis, especially in the northern region.

3. ***Can a representative BMA system be established on public lands only? If not, what area of private lands is required? How does the area requirement change if lands that are currently administratively withdrawn from grazing and timber harvest are classified as BMA lands?***

Public lands alone are insufficient to create a BMA system that adequately represents all plant community types of the Sierra Nevada, even if administratively withdrawn lands are included in the solution. Many of the foothill plant community types occur almost exclusively on private lands.

4. How sensitive is the siting of BMAs to the way in which biodiversity is measured? Specifically, how do solutions designed to represent plant community types compare to solutions designed to represent vertebrate species?

Terrestrial vertebrates are reasonably well represented in a BMA system selected for plant communities. A BMA system selected for vertebrates alone, however, has little overlap with the one for plant communities. Although the two types of solutions were comparable in the area required, there were considerable differences in the sites selected as optimal for representing vertebrates versus those for representing plant communities. Because BMAs are based on watersheds and thus implicitly include stream systems and their adjacent riparian zones, they can be designed to provide for the large proportion of wildlife dependent upon riparian habitats; their weakness in this regard is that no account is taken of upstream conditions and their potential impacts on the BMA watershed, unless explicit measures are included to consider those factors.

5. Do some areas emerge from the analysis that appear especially well suited to serve as BMAs?

Although the modeling exercise has real limitations, certain geographic areas were consistently identified in the alternatives as well suited to become BMAs, based on the biological, efficiency, and suitability criteria, and these areas therefore were less sensitive to changes in model assumptions and objectives. In the northern region, these general areas include the lower elevations in Calaveras County and portions of the Cosumnes River basin, the middle elevations of Sierra County north of Highway 49, and parts of Plumas County east of Highway 89 and south of Highway 70. Frequently selected watersheds in the central region are scattered along Highway 49, particularly in Mariposa County. Few watersheds are needed from higher-elevation zones because Yosemite National Park provides coverage for most conifer and subalpine community types. Likewise in the southern region, higher-elevation communities are generally well represented in the national parks. The areas of BMAs from the alternatives for this region tend to concentrate along the South Fork of the Kern River to Walker Pass and along the Greenhorn Mountains.

Implications

The criteria for evaluating different model alternatives were simply the area required and the total suitability of the selected watersheds. The solutions are sensitive to the size of the planning region and of the planning units (watersheds), the weights used to assign suitability, the starting BMA system, and the measures of biodiversity. The model was designed to produce solutions with minimum area and maximum suitability. However, the solutions may not be optimal with respect to other design criteria—for example, social desirability, political feasibility, economic cost, spatial arrangement of the sites to provide connected biological (especially vertebrate) habitat, or future changes in the distribution of habitats and suitability factors. The model weighting factors can be adjusted to favor certain goals, such as upstream aquatic conservation or connected riparian systems. Again, we emphasize that the purpose of the modeling was to explore possible dimensions of plausible BMA systems, rather than to identify the specific set of sites that would best meet the stated goals.

Case Study of the BMA Strategy Applied to El Dorado County

The Biodiversity Management Area strategy represents one possible management and policy solution to attain a specific set of objectives aimed at maintaining the health and sustainability of Sierra Nevada ecosystems. This strategy was formulated from a regionwide perspective, using relatively coarse ecological and social information. Implementation could require major location-specific changes in public and private institutions, economic activities, land allocations, and resource management practices.

Due to time and resource limitations, we could not analyze how the BMA strategy would play out in each local setting within the region. However, we did undertake a case study in El Dorado County. The goal in this case study was to expose some of the local ecological, economic, and institutional issues and opportunities that might arise should the BMA approach be pursued.

We examined the solutions for two BMA alternatives for the northern region (figure 5.4). The objective of both alternatives was to include at least 10% of the mapped distribution of each plant community type in lands designated as BMAs, while minimizing the total area and maximizing the suitability of the solution to meet the 10% goal. The first alternative (*A*, in figure 5.4) is based on a starting BMA system of designated parks, reserves, and ungrazed wilderness areas (Class 1 lands in SNEP's gap analysis). The second alternative (*B*, in figure 5.4) includes both Class 1 lands and Class 2 lands (national forest lands that are administratively withdrawn from intensive timber management and grazing) based on current land suitability class maps and grazing allotment boundaries.

For alternative A, fifty-four of fifty-nine mapped plant community types do not meet the 10% target for representation on initial BMA lands. The 10% solution requires fifty-five additional watersheds whose combined area is 467,000 acres or an area roughly three-fourths the size of Yosemite National Park. In this alternative, 41% of the new BMA acreage has to be on private lands, in order to cover foothill woodland, shrubland, grassland, and meadow community types that are largely in private ownership. Only 37,393 acres (18.6%) of the final BMA solution are administratively withdrawn national forest lands. Five of the selected watersheds fall within the case study area in El Dorado County.

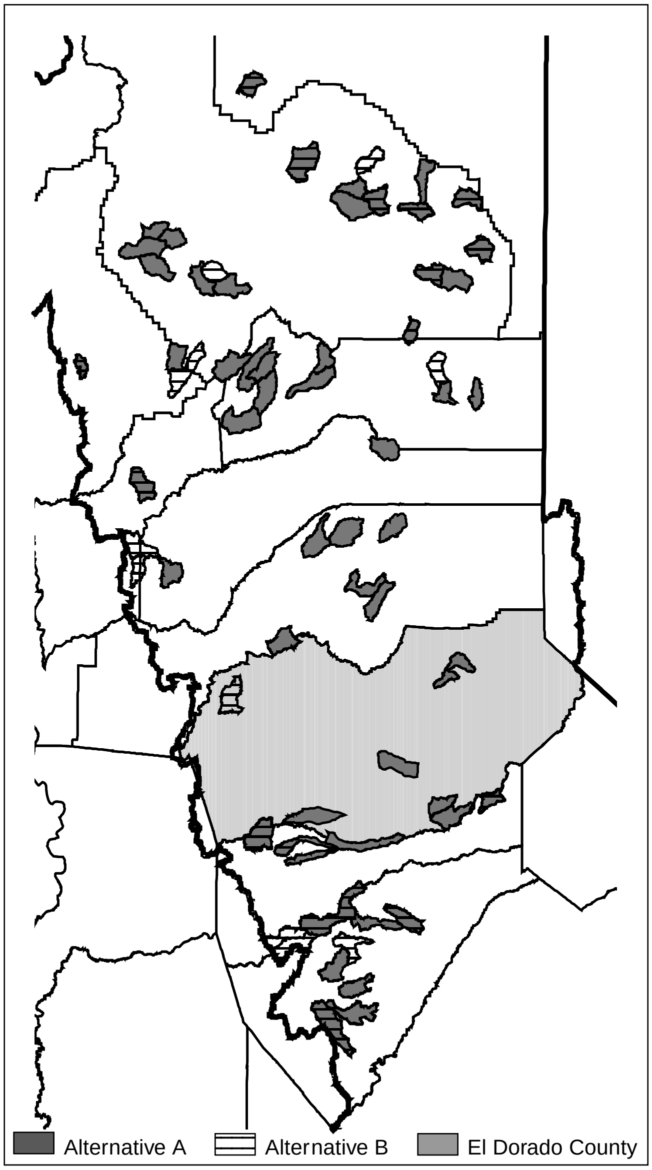

FIGURE 5.4

Case study of the BMA strategy. Two alternative BMA networks for the northern region, both of which have objectives of including at least 10% of the mapped distribution of each plant community type in lands designated as BMAs, while minimizing the total area and maximizing the suitability of the solution. Alternative A (darkly shaded polygons) shows BMAs needed in addition to Class 1 lands (designated parks, reserves, and ungrazed wilderness areas). Alternative B (cross-hatched polygons) shows BMAs needed in addition to Class 1 lands and Class 2 lands (national forest lands that are administratively withdrawn from intensive timber harvest and grazing). Class 1 and Class 2 lands are not shown. El Dorado County is shaded for reference. (From volume II, chapter 58.)

The area required in alternative B, which begins with Class 1 and Class 2 lands, is considerably less than that of alternative A, because the Class 2 lands account for many of the middle-elevation forest and shrubland community types. Under this alternative, 10% of the region is initial BMA lands and only thirty-six of fifty-five plant community types require additional representation. The solution requires twenty-five additional watersheds whose area totals 216,029 acres. Because middle- and high-elevation types are relatively well covered, watersheds are selected mainly from the foothill zone. Nearly half of the new area is selected from private lands in order to represent foothill plant community types.

Black Rock Creek Watershed

The solutions to BMA alternatives A and B were examined from a more local perspective using census and zoning data for El Dorado County. For example, one of the watersheds selected in a BMA alternative (see volume II, chapter 58) is the Black Rock Creek watershed near the towns of Cool and Pilot Hill (plate 5.3). This watershed, which was selected in four of nine model BMA alternatives for the northern region, is 9,312 acres and is entirely privately owned. The vegetation cover is a mosaic of foothill types dominated by foothill pine–oak woodland, interior live oak woodland, black oak woodland, annual grassland, and riparian woodland. Despite the lack of public lands, the watershed suitability index (WSI) is relatively low (i.e., the predicted suitability of this watershed for BMA status is high) based on mapped population density and roads.

For the Black Rock Creek watershed to meet the definition of a BMA it would have to be managed holistically to maintain native biodiversity associated with oak woodlands, grasslands, and riparian ecosystems. This might include such activities as (1) limiting and consolidating any future road construction and residential development to minimize fragmentation of habitats, (2) adaptive management of livestock grazing in upland environments to ensure adequate oak regeneration, promote native herbs, and reduce cover by noxious, non-native weeds, (3) enhanced protection and restoration of riparian areas, (4) controlled burning to restore or maintain specific upland plant and animal communities, and (5) systematic ecological monitoring of upland, riparian, and aquatic environments.

Although at present the watershed has many biological and environmental attributes that make it attractive for BMA status, the presence of multiple private landowners and the proximity to Auburn and other expanding municipal areas would require collaborative planning for BMA management, especially in the future. In the General Plan for El Dorado County, Black Rock Creek watershed is zoned primarily low-density residential and rural residential, with the exception of areas in the vicinity of Cool and Pilot Hill that are zoned medium- to high-density residential (plate 5.4). In contrast, the Alternative General Plan calls for a large block of open space in the southern half of the watershed and an increase in me-

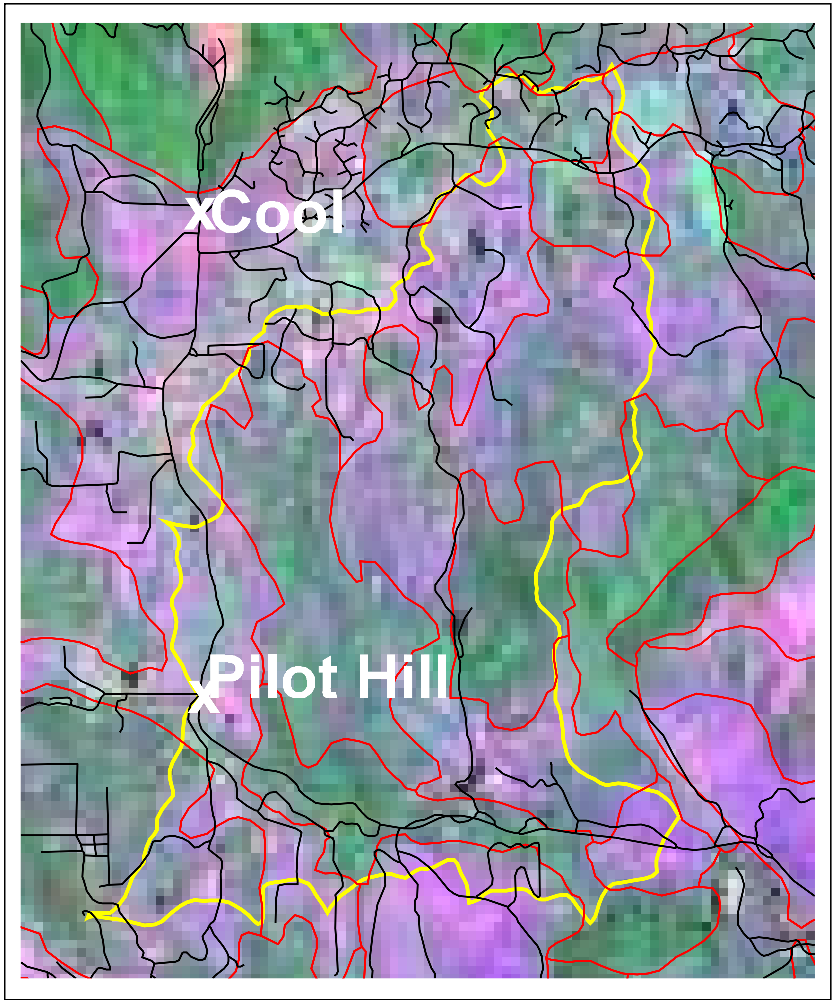

PLATE 5.3

Satellite image (from Thematic Mapper) of the Black Rock Creek planning watershed, Biodiversity Management Areas Case Study for El Dorado County, showing the watershed boundary (yellow line), vegetation units (red lines), and roads (black lines). (From volume II, chapter 58.)

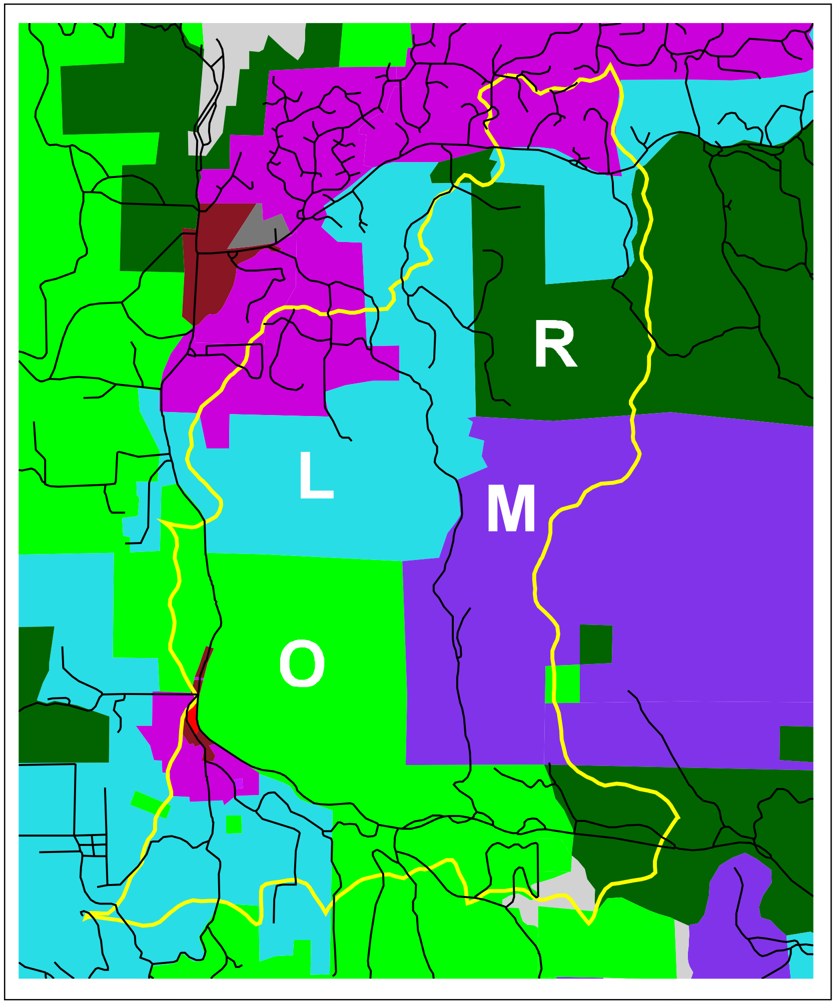

PLATE 5.4

Land zoning in the Black Rock Creek watershed under the proposed general plan for El Dorado County, Biodiversity Management Areas Case Study. R = rural residential, L = light residential, M = medium residential, O = open space. (From volume II, chapter 58.)

dium-density residential zoning in the eastern watershed. Full buildout based on either of these county plans would require extensive road construction and new housing and would lower the suitability of the watershed for BMA status. On the other hand, the high land values in these areas may provide an opportunity: nearby lands might be sold for development and the proceeds used as a conservation land bank to fund creation and maintenance of a BMA in this area.

Prothro Creek Watershed

Prothro Creek watershed is one of several selected from the upper Cosumnes Basin as part of the solution to one BMA alternative (see volume II, chapter 58) (plate 5.5). As we noted earlier, this alternative starts with Class 1 lands as the BMA system and requires additional area for most middle- and high-elevation forest types as well as for foothill plant community types. The Prothro Creek watershed was selected to contribute area in Sierran mixed conifer forest, west-side ponderosa pine forest, Jeffrey pine forest, red fir forest, mixed montane chaparral, and montane manzanita chaparral. The watershed is located on the southern edge of El Dorado County, just northwest of Lower Bear River Reservoir. It is 9,257 acres in area and is 92% public land, 8% industrial timberland. Population density is very low, but 34% of the watershed was mapped in roaded area.

Management of the Prothro Creek watershed as a BMA would likely be oriented toward maintaining native biodiversity in montane forest, notably Sierran mixed conifer and red fir types. This could include (1) fire management to reduce the likelihood of severe, stand-replacing fires, (2) implementing silvicultural systems to attain desired forest compositional and structural properties on different sites, (3) removal or repair of some logging roads, (4) protection and restoration of aquatic systems and riparian buffers, (5) systematic monitoring and adaptive management of biota and ecosystem processes.

Roughly 10% of the watershed is mapped by the Eldorado National Forest as unsuitable for intensive timber harvest (plate 5.6), including a large Spotted Owl Habitat Area (SOHA) in the western half and riparian zones throughout the watershed. The late successional old-growth (LSOG) mapping team divided the Prothro Creek watershed into three polygons: two lower-elevation polygons mapped as montane mixed conifer and one higher-elevation polygon mapped as upper montane red fir. These labels are consistent with the GAP vegetation map, which divided the watershed into ten polygons. The LSOG mappers assigned the red fir polygon a rank of 3, and the two mixed conifer polygons ranks of 1 and 4 (see chapter 6). The two mixed conifer polygons were included in an Area of Late Successional Emphasis (ALSE) that extends to the south and west.

The Prothro Creek watershed highlights several features of the BMA strategy. First, the watershed encompasses a wide range of elevations and ecosystem types, and an effective management plan would have to account for these different types and their juxtaposition in the landscape. In this sense a BMA is quite different from many reserves—for example, U.S. Forest Service Research Natural Areas—that target one or a few ecosystem types. The presence of industrial timberland adds another layer of management complexity to this watershed.

Much of the lower watershed was recently harvested for timber, and, although the area is included in at least one proposed ALSE system, it was given an LSOG rank of 1. This illustrates the point that, because the GAP vegetation database does not include detailed structural information, the BMA solutions do not account for seral stage in representing forest types and thus could include recently burned or logged areas. Perhaps 60% of the Prothro watershed is in rank 3 red fir or rank 4 mixed conifer forestlands that are also classified as suitable for intensive timber management. Thus another concern in designating this watershed as a BMA is possible reduction of the commercial timber base in the Eldorado National Forest.

Management Implications

The case study of watersheds in El Dorado County (only two of which are summarized here; for more, see volume II) serves to emphasize the multisector, multijurisdictional nature of biodiversity conservation in the Sierra Nevada. Virtually every BMA that was examined included both private and public lands. One BMA spanned two counties, and another included both public and private industrial timberlands. It is difficult to envision how a regionally designed BMA strategy, implemented in the form of watershed-based ecosystem management aimed at native biodiversity, could be undertaken or succeed without transfer of management rights to a single administering agency, unless much more effective interaction and collaboration occur between the public and the private sectors and among local, state, and federal agencies.

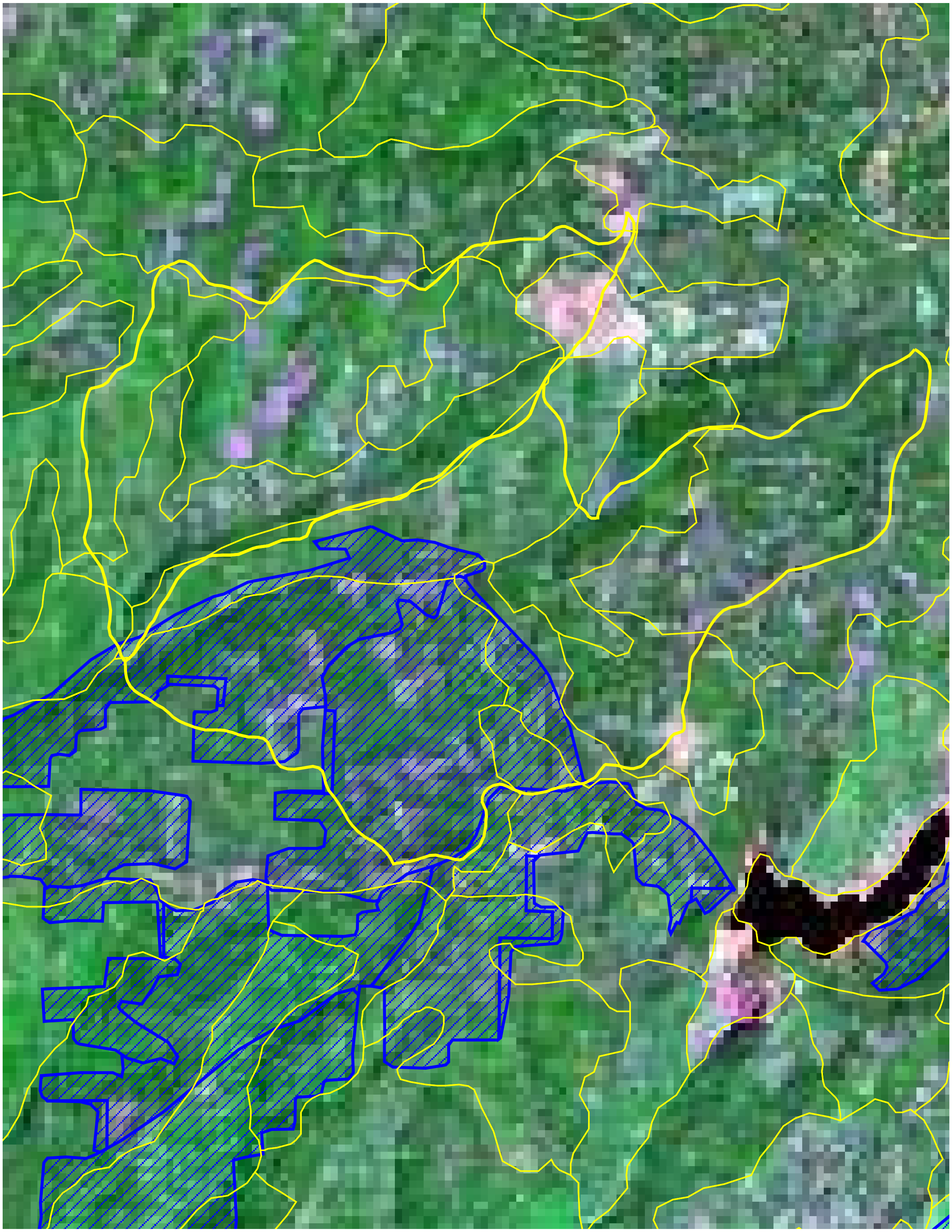

PLATE 5.5

Satellite image (from Thematic Mapper) of the Prothro Creek planning watershed, Biodiversity Management Areas Case Study for El Dorado County, showing the watershed boundaries (thick yellow lines), vegetation units (thin yellow lines), and SNEP Areas of Late-Successional Emphasis (purple hatching). (From volume II, chapter 58.)

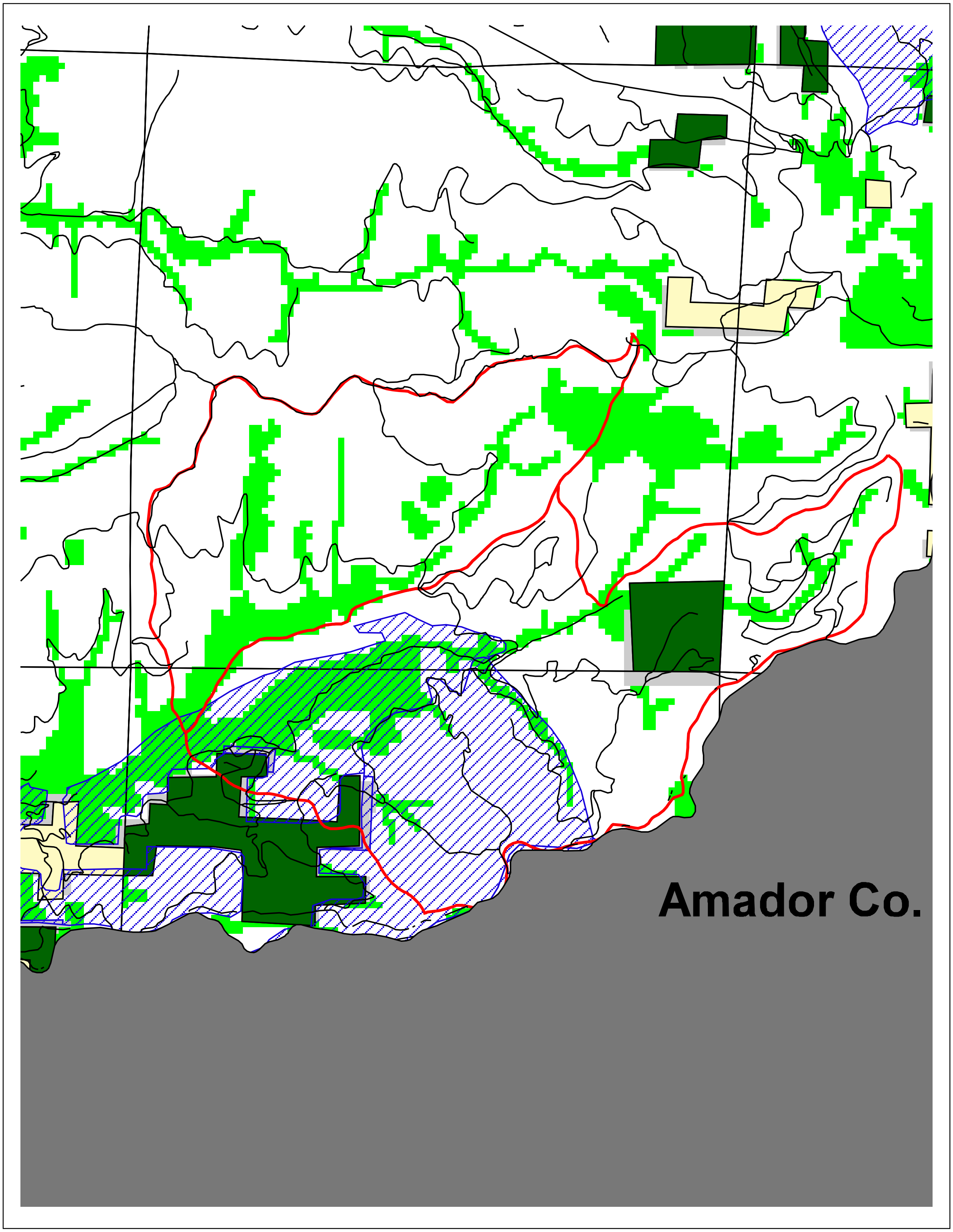

PLATE 5.6

Map of the Prothro Creek planning watershed, Biodiversity Management Areas Case Study for El Dorado County, showing private industrial timberlands (gray-green), USFS lands classified as suitable (white) or unsuitable (bright green) for intensive timber harvest, other ownership (light yellow), roads (black lines), BMA watersheds (red lines), and Areas of Late-Successional Emphasis (hatching). (From volume II, chapter 58.)

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