CHAPTER 1

Sierra Nevada Ecosystems

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❈ CRITICAL FINDING

Climate Change During the period of recent human settlement in the Sierra Nevada, climate was much wetter, warmer, and more stable than climates of the past two millennia; successful ecosystem evaluations and planning for the future must factor climate change into analyses.

INTRODUCTION

The Sierra Nevada evokes images particular to each individual's experience of the range. These images take on the quality of immutability, and we expect to find the range basically unchanged from one year to the next. The Sierra Nevada, however, including its rocky foundations and the plants and animals that inhabit it, changes continually through time. Ecosystems respond to cumulative effects from the past; the old-growth forests in the Sierra today evolved under different conditions from those of the present. To understand how the landscapes of the Sierra Nevada are changing, and what role humans have in shaping the future, we benefit by knowing what makes up the current Sierra as well as key factors influencing change. This was the point of departure for the Sierra Nevada Ecosystem Project. A brief introduction to the Sierra Nevada and the context of the study are presented here; subsequent chapters summarize the study's findings.

FIGURE 1.1

Northern Sierra montane aerial view. (Photo by Jerry F. Franklin.)

ROCK AND SOIL

At its foundation, the Sierra Nevada is an enormous deposit of granitic rock whose exposed slopes are readily visible at the crest of the range. The gradual west slope rising from the expansive Central Valley to the Sierra crest is dissected by deep, west-trending river canyons. At the eastern edge of the uplift, the high peaks dominate the uppermost elevations, forming rolling highlands in the north—with elevations mostly less than 9,000 feet (figure 1.1)—and expansive, highly dissected mountains in the broad southern alpine zones, where Mount Whitney (highest peak in the contiguous forty-eight states) rises to 14,495 feet. The range ends abruptly at the eastern escarpment, dropping with a shallow gradient in the north, but in the south plunging more than 10,000 feet from the Sierran crest to the floor of the Great Basin.

❈ *The SNEP Study Area*

The core area boundary for the Sierra Nevada Ecosystem Project was the area containing the headwaters of twenty-four major river basins and extending through the foothill zone on the west side and the base of the escarpment on the east side (figure 1.2). No single boundary adequately defines all the ecological components, but watersheds are in many ways the most discernible and to many biota the most meaningful ecological units in the Sierra. At the request of Congress, a larger study area for the project included portions north of the physiographic Sierra Nevada and extensions beyond the core area to the south and east. Appropriate adjustments to these boundaries were considered in SNEP analyses pertinent to the needs of each issue.

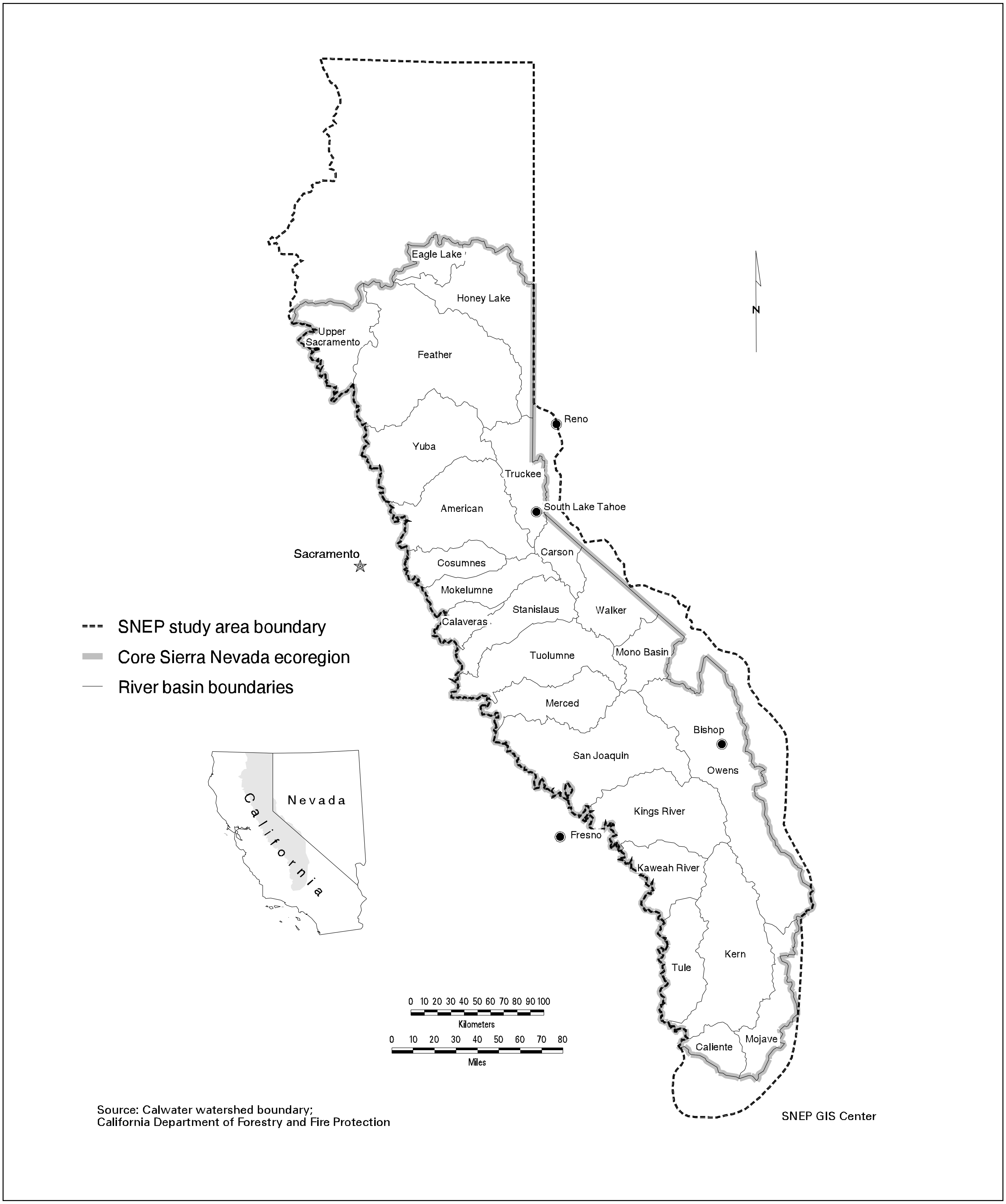

FIGURE 1.2

Boundaries of the core Sierra Nevada ecoregion, the study area, and the twenty-four river basins used by SNEP in its assessments.

As a geological feature, the Sierra Nevada is relatively distinct. The western boundary is defined as a contact between old, harder rocks of the Sierra Nevada and their eroded and redeposited younger by-products at the edge of the Central Valley. At the north, the older rocks of the Sierra Nevada are overlain by younger volcanic rocks of the southern Cascades in the Mount Lassen area. The eastern edge of the range follows the base of the Sierran escarpment. At the south, the geologic Sierra Nevada abuts the structurally distinct Tehachapi Mountains, forming a discernible boundary in southern Kern County.

The Sierra Nevada's environmental history has been shaped over several hundred million years by varying intensities and forms of uplift, erosion, volcanism, and glaciation. Plate tectonics and climate variations acting at millennial, decadal, and annual timescales interact to influence the intensity of these events and their impacts on the landscape. These diverse geological activities have produced a broad suite of rock formations in the Sierra Nevada, dominated by granite but including many types of igneous, sedimentary, and metamorphic rocks, with ages from Cambrian (about 500 million years ago) to Quaternary (the past 2 million years). Most evidence suggests that the modern range is about 10 million years old, although very recent and controversial evidence suggests a much older age.

Rocks of the Sierra Nevada interact with climate, topography, surface processes, and biota to create Sierra Nevada soils. Because the Sierra Nevada is underlain by mostly granitic rocks, soils that develop from these foundations are thin and rocky. Although the nutrient capital (fertility) of the soil in general over the Sierra Nevada is rather low, the range contains some of the most productive sites for conifers in the world. Soil types form a mosaic across the Sierra, influencing vegetation, erosion, wildlife distribution, water quality, fertility, and a myriad of human uses.

Such a complex geological and soil foundation has dramatic implications for human uses of Sierra Nevada ecosystems. Mesozoic deposits (more than 100 million years old), altered through pressure and heat and exposed through erosion or buried deep underground, form the gold and silver that attracted a rush of miners and began the period of Euro-American settlement. Abundant sediments from ancient seafloors, lake beds, and water-carried deposits create the ore and gravel resources that are the contemporary valuable rocks of the Sierra (plate 1.1). Persistent seismic activities, especially along volcanic vents of the eastern escarpment near Mammoth Lakes and Markleeville, are a focus of concern for urban development in these areas, yet those same vents provide geothermal power for existing communities. The rich and fertile soils that have formed on the western edges of the Sierra Nevada continue to support a diverse agriculture that had its origins in the Native American communities that occupied the region.

Volcanic and seismic activity is highly localized but ongoing in the Sierra Nevada. New volcanic craters have been built, vents have erupted, hot springs have formed, faults have slipped, and volcanic-induced mud slides have occurred as recently as the past hundred years in a few regions. Volcanic events will undoubtedly persist as agents of change affecting local ecological and human elements of Sierran ecosystems and demanding local attention.

CLIMATE

Major climate change has occurred at millennial, decadal, and annual scales in the history of the Sierra Nevada (figure 1.3). The regional climate developed from warm, wet, tropical conditions about 65 million years ago through a cycle of at least eight major glacial and interglacial periods of the last million years to the winter-wet, summer-dry pattern of the last 10,000 years. These climatic periods have greatly influenced vegetation, animals, and human populations; their effects are observable today and influence how people manage resources. For instance, two extensive droughts, each lasting 100 to 200 years, occurred within the last 1,200 years. During the cold phase of the Little Ice Age (about A.D. 1650–1850), glaciers in the Sierra Nevada advanced to positions they had not occupied since the end of the last major ice age more than 10,000 years ago. The period of modern settlement in the Sierra Nevada (about the last 150 years), by contrast, has been relatively warm and wet, containing one of the wettest half-century intervals of the past 1,000 years. Many of the forests that stand today were established under different climates—generally wetter ones—from the present regime.

The current Sierran climate is dominated by a "mediterranean" pattern of a cool, wet winter followed by a long dry period in summer. High yearly variability in temperature and precipitation is also characteristic. Because of the influence of the Pacific Ocean and storm tracks from the west, strong climatic gradients develop with elevation from west to east. At foothill altitudes, summer hot, dry climates predominate; as elevation increases, so does precipitation. Winter storms are moisture-laden and release enormous precipitation on the west slope. In winter, snow covers the landscape to about 6,000–8,000 feet. The transition zone of rain to snow is an important determinant of vegetation types, stream dynamics, and human settlement.

The Sierra summits wring water from the winter storms and summer convection systems, leaving the eastern flank progressively drier each mile east (figure 1.4). From moist mountain ecosystems at the Sierran crest, the transition to semiarid desert near Bishop, for example, can occur in less than two horizontal miles. The west shore of Mono Lake, at the base of the Sierran escarpment, receives an average of 12 inches of rain annually, whereas the eastern edge, lying in Great Basin steppe, receives only 6 inches. Strong gradients of aridity also exist from north to south along the Sierran axis as a result of the location of jet stream and subtropical high pressure cells.

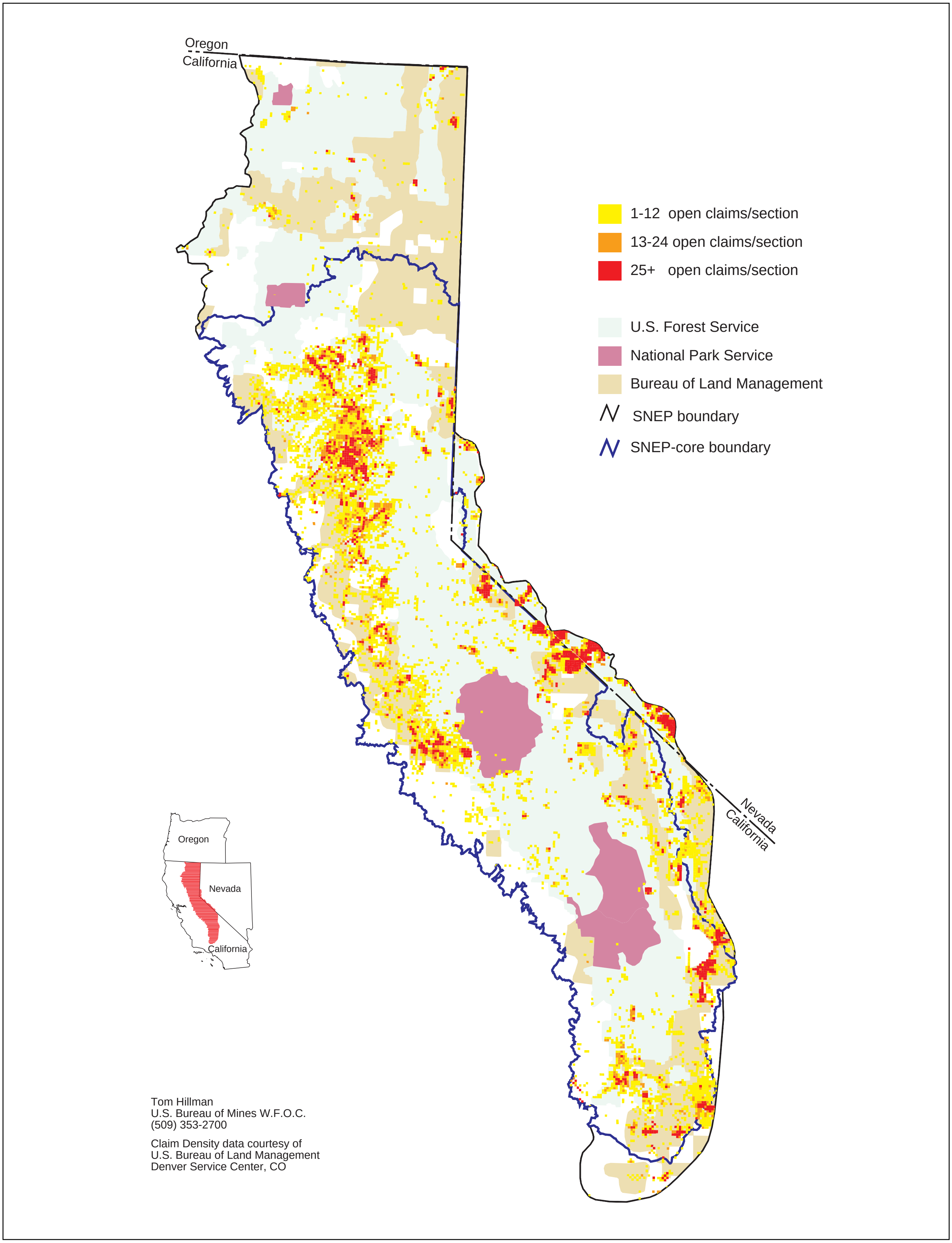

PLATE 1.1

Total mineral claim density per section in the SNEP study area. (From volume II, chapter 18.)

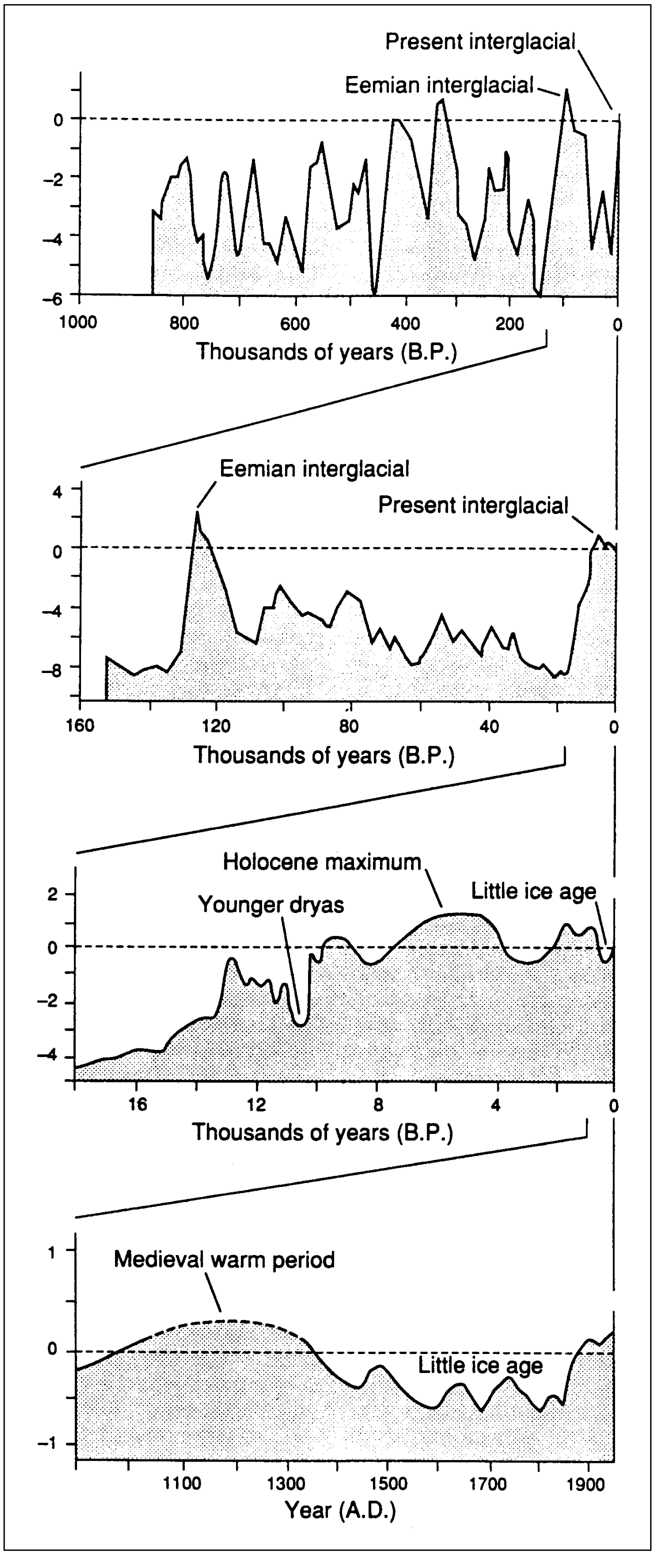

FIGURE 1.3

Global temperatures (relative changes based on oxygen isotopes) at four time scales. (From volume II, chapter 4. Reprinted by permission of the Society for Range Management.)

Climatic and geological forces are the royal architects of Sierra Nevada ecosystems. Water, wildfire, plants, fauna, and humans are highly dependent on regional climate and local weather. Organisms must adjust (migrate, adapt) or die as climate changes. The current patterns of vegetation, water flow and abundance, and animal distribution in the Sierra are determined largely by cumulative effects of past and present climates. Human development in the Sierra has proceeded during a temporary period of relatively wet, warm climate. Patterns of human settlement, perceptions of wildfire, design of water delivery systems, predictions of water availability, future forest and urban planning, and aesthetic expectations about forest condition (size, composition, health of forests) are based largely on conditions of this anomalous climate period. One implication of a longer view of climate is, for instance, that the "droughts" of the mid-1970s and mid-1980s were actually not droughts at all, relative to the century-long dry periods that have been common in recent Sierran climate history.

WATER

Water is an essential and often limiting factor for life. Given strong seasonal mediterranean patterns, high annual variability of climate, natural aridity of the eastern flanks, and the constant thirst of plants, animals, and burgeoning human communities adjacent to the Sierra, water remains a subject of intense competition for all Sierran biota.

Water partitions the Sierra into twenty-four readily discernible river basins or watershed units (figure 1.2). The Sierran crest divides water flow either west to the Pacific Ocean or terminating in the San Joaquin valley, or east into the Great Basin, where the water evaporates. To the west, the major watersheds are defined by the Feather, Yuba, American, Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, Kaweah, and Kern Rivers; to the east, by the Truckee, Carson, Walker, and Owens Rivers. Streams, creeks, and temporary waters define subwatersheds at increasingly smaller scales within these areas.

Watersheds at each scale are important to creatures that inhabit water. Sierra Nevada waters are home to a diverse aquatic biota, including fishes, amphibians, invertebrates, and plants. To denizens of rivers, the landscape is defined and limited by linear connections; the arterial nature of water systems isolates aquatic populations. Watersheds also isolate aquatic organisms, so that entirely different aquatic biotas may exist from one watershed to another. Rivers and their watersheds extend beyond the geologic edges of the Sierra Nevada to their final destination in ocean, valley, or basin. Fish and other aquatic life have evolved to occupy habitat zones within certain elevations along the rivers, but they do not have sharp or readily defined downstream or upstream boundaries (figure 1.5).

FIGURE 1.4

Mount Tom and the steep eastern escarpment of the Sierra Nevada, with piñon woodlands at the base. (Photo by Deborah L. Elliott-Fisk.)

At middle and low elevations, the Sierra Nevada once supported a diverse fish population, including anadromous species such as chinook salmon. Extensive and abundant populations of frogs and salamanders inhabited Sierran streams, lakes, and meadows. The largest numbers of aquatic species in the Sierra Nevada are the little-known invertebrates. The many lakes of the high Sierra, once mostly fishless, originally supported a diversity of aquatic amphibian and invertebrate species. These groups of aquatic animals have been extremely vulnerable to changes in their habitat, and the story of their composition and distribution is now quite different from that of the past.

PLANTS AND VEGETATION

The Sierra Nevada today is rich in vascular plant diversity, with more than 3,500 native species of plants, making up more than 50% of the plant diversity of California. Hundreds of rare species and species growing only in the Sierra Nevada (endemics) occupy scattered and particular niches of the range. The assemblage of plants growing together in an area creates characteristic vegetation types. Vegetation is a dominant element of ecosystems, for plant diversity, for ecological functions plants engage in (e.g., soil aeration, microclimate alteration), and as habitat and sustenance for other organisms. The architecture of each vegetation type creates habitat suitable for some species and unsuitable for others. The distribution of wildlife is closely associated with the distribution of vegetation, and the same is true for less visible and less familiar forms of life such as fungi, bacteria, and insects.

The major vegetation zones of the Sierra form readily apparent large-scale elevational patterns. Unlike aquatic systems, whose dominant Sierran pattern is defined by east-west watersheds, primary vegetation types of the Sierra form north-south bands along the axis of the Sierra. Major east-west trending watersheds that dissect the Sierra into steep canyons form a secondary pattern of vegetation in the Sierra. Diversity of regional and local plant species as well as vegetation types in the Sierra Nevada are highly influenced by climate,

❃ *Ecosystems*

Ecosystem refers to the collective entity formed by the interaction of organisms (e.g., plants and animals) with each other and with their physical environment (e.g., soil, water, weather) at a particular location. SNEP considers people, when they are present, as part of ecosystems. Ecosystems exist at many, potentially overlapping, scales, from a rotting log to the entire Sierra Nevada; they all have three fundamental attributes. *Components* are the kinds and numbers of organisms (biodiversity of genes, individuals, populations, species, and groups of species) and physical elements (soil, rock, water) that make up the ecosystem—the "pieces." Trees and wildlife are important to Sierran ecosystems but equally important are the myriad less visable or unseen organisms, such as insects, fungi, and bacteria. *Structures* are the spatial distributions of the components—the way the ecosystem "pieces" are arranged at a location and time in the ecosystem. Plant communities, such as the mixed conifer forest, and forest structure, such as old-growth stands, are important examples of ecosystem structure. *Processes* or *functions* refer to the flow or cycling of energy, materials, and nutrients among the components over space and through time. Processes are the work of the ecosystem; they contribute to changes in the components and the structure of the ecosystem. Ecosystems are linked to one another, so that changes in components, structure, and function in one ecosystem may have consequences in contiguous and noncontiguous ecosystems.

elevation (temperatures), and soil type. From an aerial perspective, it is obvious that only part of the Sierran landscape is forested, the rest being meadow, chaparral scrub, woodland, savanna, canyon land, alpine habitat, bare rock, and water. As might be expected, the boundaries of the Sierran floristic province differ from boundaries defined by geology, watersheds, aquatic diversity, or wildlife, especially at the northern and southern edges of the range.

At the lowest elevation on the west side, interfingering with the Central Valley grasslands and chaparrals, are the foothill woodland vegetation types. These woodlands are unique to California, although not to the Sierra (they extend around the Central Valley), and include several deciduous and evergreen oaks as well as foothill pine. Tree cover here ranges from open savannas to lush riverside forests. Of all the Sierran vegetation types, the foothill plant communities have supported the most native biodiversity and highest human populations during the last few centuries. Now these are most at risk of loss by conversion to human settlement.

Intermixed with the foothill woodlands are a large group of dense shrublands called chaparral. Although chaparral vegetation looks similar throughout the range, there is great variation in species composition from one location to another. Many factors determine the location of chaparral types, but generally they are restricted to rocky soils with low fertility. The mediterranean climate is an overriding environmental factor in the ecology of Sierran chaparrals, including the climate's promotion of frequent burning in intense wildfire. The boundary between chaparral and forest is dynamic and determined partly by wildfire. Shrublands on the east side of the Sierra Nevada are the Great Basin sagebrush steppe and bitterbrush vegetation types, which begin near the base of the eastern escarpment and extend across the vast expanse of the Great Basin. These arid shrublands have much less species diversity than west-slope chaparrals.

Depending on latitude, a broad conifer zone begins at elevations between 1,000 and 3,000 feet on the west and between 3,000 and 5,000 feet on the east side. Ponderosa pine (mixed with hardwoods) dominates the lower western mon-

FIGURE 1.5

Aquatic and riparian ecosystems in healthy condition provide critical habitat for Sierra plants and animals. (Photo by Jerry F. Franklin.)

FIGURE 1.6

Mixed conifer forest with giant sequoias, Kings Canyon National Park. (Photo by Constance I. Millar.)

tane zones, whereas at lower elevations on the east side, piñon pine and juniper, then Jeffrey and ponderosa pine forests occur. Above these zones on the west side is the commercially important mixed conifer forest type (figure 1.6), typified by varying mixtures of Douglas fir, ponderosa pine, white fir, sugar pine, and incense cedar. On the eastern front, this mixed conifer zone is less diverse, and species mixes vary more from place to place than on the west side.

With increasing elevation , the mixed conifer zone gives way to a fir belt—first white fir, then predominantly red fir. The location of this shift in forest type depends on the transition from rain to snow, which varies with elevation at a particular latitude, shifting uphill farther south in the range. The fir zone is less extensive on the east side; south of Lake Tahoe, only a few pockets exist. Trees become shorter and more scattered with increasing elevation. The subalpine zone is a mixture of vegetation types and distributions, ranging from clusters of dense hemlock or lodgepole pine to open forests of limber pine or western white pine, to sparse, mostly rock-slope types containing whitebark pine, foxtail pine, and western juniper. Above this zone is alpine vegetation adapted to the cold, dry conditions of the highest Sierran elevations; trees give way to low shrubs and finally cushion-plant communities that grow among rock crevices in a zone of ice and wind.

As one drives or hikes through the Sierra, it is obvious that each vegetation type is in itself a mosaic. Small changes in topography, differences in soil and rock characteristics, and the history of disturbance (fire, storm blowdown, insect and pathogen activity, avalanche) contribute to the complex mixture of patches that characterizes Sierran forests. Plant patterns vary not only from place to place in the Sierra but also over time. This complexity at the local scale makes it difficult to map vegetation, to generalize relationships of structure to function, and to assess forest conditions.

Characteristic structure and function develop in Sierran forests as they age. Under aboriginal conditions, fires and other disturbance events regularly burned entire stands of trees, leaving openings that passed through continuous but distinctive phases as they aged. This succession of a forest through time between major disturbances is important for plants and animals that use different stages as habitat. Different ecological functions develop with successional phase in a forest. From seedling colonists to mature forest stands, forests develop in structural complexity and species composition until they reach a stage known as late successional, or, more popularly, old growth.

We know most about late successional/old-growth attributes—and the relationships of structure to ecological function—in middle-elevation conifer forests, specifically mixed conifer, red fir, and east-side pine. A dominant feature in middle-elevation forests is the spatial variability that develops as a result of succession in Sierran forests. In these and other vegetation types of the Sierra, wildfire, which was a frequent characteristic of presettlement conditions, has been an architect and important ecological agent of forest and stand structure. The vagaries of fire, from low to high intensity, small to large areas, contribute to the great variability that typifies Sierran middle-elevation forests. Each stand passes through its own history, thus developing a distinctive structure. Various events (tree fall, windfall, avalanche, fire hot spot, insect outbreak) create small and large openings in some areas, whereas other areas maintain standing trees (alive and dead) despite disturbance. Patches develop a characteristic structure in their abundances of large, old trees (relicts left after ground fires); multiple age-classes of live trees; mixtures of dominant species; snags and downed woody debris of different sizes and degrees of deterioration; closed crown canopy; and layers of vegetation. Collectively the forests containing these patches are highly heterogeneous. The image evoked popularly by the term *old growth*, i.e., extensive uniform stands of even-aged, old trees, although descriptive of some Pacific Northwest forests, is inappropriate to the complex and heterogeneous Sierran forests.

The forests of the Sierra are part of the river of change in the mountain range. Many of the current vegetation distributions have been in place locally for only a few thousand years. At shorter intervals within that time, changes in individual distribution have occurred. For instance, during the Little Ice Age of the last centuries, tree lines dropped and forest densities and wildfire patterns changed; during the warm centuries of the last millennium, many species grew in different locations from their current sites, wildfires burned in different patterns, and water flows and lake levels were very low. During the glacial-interglacial periods, most vegetation zones shifted altitudinally up and down by as much as 1,600 feet; throughout the millennia before the ice ages, vegetation types of the region were vastly different from anything we see in the Sierra now. Today Sierran forests show the effects of decades of fire suppression, which has changed the character of many forests even in places otherwise minimally influenced by humans, such as the national parks.

ANIMALS

About 400 species of terrestrial vertebrates (including mammals, birds, reptiles, and amphibians) use the Sierra Nevada, although only a fraction are restricted to the range. Animals that live in the Sierra Nevada depend greatly on the distribution and quality of vegetation for their habitat and food needs. Many native Sierran species are adapted to habitats maintained by the precontact fire regime (the regime that prevailed before non-Indian settlement of the area). Although only a handful of species require late successional habitats, many more depend on the presence of large, old trees, snags, and logs in Sierran woodland and forest communities for some part of their life cycle. Late successional and riparian forests are important habitats to wildlife, as are the low-elevation foothill woodland types. In the latter zone especially, conversion of habitat and loss of ecological function have dramatically altered the suite of species that flourished in these communities. A common and important pattern for Sierran birds is their migratory patterns up and down slopes, following seasons. When a specific habitat needed for completion of a critical life stage (e.g., foothills for breeding) is disrupted, species may be put at risk even if they are able to use alternative habitat for other needs.

❄ *Insect Species Found Only in the Sierra*

The following numbers of known endemic terrestrial insect species are found in each of the major river basins in the SNEP study area. (From volume II, chapter 26.)

Eagle Lake	0
Honey Lake	0
Feather	2
Upper Sacramento	0
Yuba	1
Truckee	7
American	0
Carson	2
Cosumnes	0
Mokelumne	4
Walker	2
Stanislaus	0
Calaveras	0
Mono Basin	6
Tuolumne	7
Owens	17
Merced	0
San Joaquin	3
Kings	1
Kaweah	3
Kern	3
Tule	1
Caliente	2
Mojave	0

HUMANS IN THE SIERRA

Humans are an integral part of Sierra Nevada ecosystems, having lived and sustained themselves at various elevations in the region for at least 10,000 years. Indigenous populations were widely distributed throughout the range at the time of European immigration. Archaeological evidence indicates that for more than 3,000 years Native Americans practiced localized land management for utilitarian purposes, including animal hunting, forest burning, seed harvesting, pruning, irrigation, and vegetation thinning. These practices no doubt influenced resource abundance and distribution in areas of early human settlement. On a longer timescale, humans may have played a role in the decline of large vertebrates during prehistoric times. Extinction of a large and diverse megafauna throughout western North America, including the Sierra Nevada, at the end of the last major ice age (around 10,000 years ago) coincided with the arrival of humans in North America. Some scientists link these extinctions to overhunting by humans of animals already stressed by changing environments.

Immigration of non-Indian settlers in the early 1800s began a period of increasingly intense resource use and settlement. By the late 1800s, parts of the Sierra had been transformed as a result of intense interest by these immigrants in Sierran resources. Agriculture, mining, logging, and grazing activities were extensively practiced in many regions of the Sierra. The need to divert water to support resource extraction and settlement led to a major reordering of natural hydrological processes through a vast network of ditches and flumes. In some areas, impacts from early use of the Sierra created rapid and irreversible changes from precontact conditions.

By the early 1920s, a new phase of Sierran history was emerging, in which resource use was more regulated and forest and range protection was emphasized. Suppression of fires became a primary goal of federal, state, and private efforts, controls were imposed on the timing and locations of grazing, and timber harvest was systematized under government and industrial forestry programs. Although trends of use have varied over the last 150 years, increasing population pressure and complex demands on Sierran resources pose serious ecological threats in some regions and severe management challenges elsewhere. Similarly, changing values for natural resources present economic and social challenges to rural communities within the Sierra Nevada.

SOCIAL INSTITUTIONS

The web of institutions laid across the Sierra by successive generations of Americans is central to an understanding of the mountain range and its future management. This web is the eventual target of the current study, in that the project's assessments and strategies must be absorbed, adapted, and implemented not by the biology or geology of the mountain range but rather by the institutions through which human society operates.

Institutions are central elements in the ecology of the Sierra Nevada because they mediate the relationship betwen the labor and desires of people and the Sierran ecosystems those people use. In a biological analogy, institutions—the governmental and nongovernmental organizations, agreements, and regulations—constitute a key part of the life history strategy that the human species currently uses in the Sierra. Institutions are in large measure how people link themselves to other parts of the ecosystem.

Institutions govern not only what people extract from the ecosystem—water, timber, recreation, amenities—but also how they reinvest in the natural capital through actions such as planting trees or restoring habitats. The extent to which institutions and policies "close the loop"—that is, mitigate the environmental impact of human activities—is a critical part of a Sierra Nevada ecosystem assessment.

As institutions regulate the exchanges between people and the ecosystem, they also link people who reside outside the mountain range with the ecosystem within it. Institutions that close the loop by extracting water or reinvesting (for instance, in hatcheries to mitigate for habitat loss) are also closing a loop that passes beyond the Sierra to include urban and agricultural water users in the San Francisco Bay Area, southern California, and the Central Valley. Closing the loop, then, includes identifying and accounting for the values of all stakeholders in the Sierra Nevada, regardless of their locations within or outside the range and understanding how benefits and costs flow among coupled ecosystems.

Although institutions are part of the ecology of the Sierra, nothing ensures that those institutions perceive the entire ecosystem, much less manage it in a sustainable manner. Heretofore, institutions have largely focused on portions of ecosystems. For instance, for streams on the east side of the Sierra, the Lahontan Regional Water Quality Control Board has jurisdiction over the quality of water, the California Water Resources Control Board over the rights to the water, the California Department of Fish and Game over the trout in the water, and the U.S. Forest Service and the state Department of Forestry and Fire Protection over the trees that grow next to the water. Jurisdictions split along geographic as well as resource lines. The U.S. Forest Service and the National Park Service manage the land along the upper reaches of most Sierran rivers, while private landowners, the federal Bureau of Land Management, municipal utilities, and local irrigation districts manage much of the land along the lower reaches. There are no existing mechanisms to ensure that the sum of the management of the parts of the ecosystem adds up to wise management of the whole ecosystem.

Like all other parts of the Sierran ecosystem, the institutional components change over time in response to larger forces.

❄ Land Ownership and Reserve Allocation in the Sierra Nevada

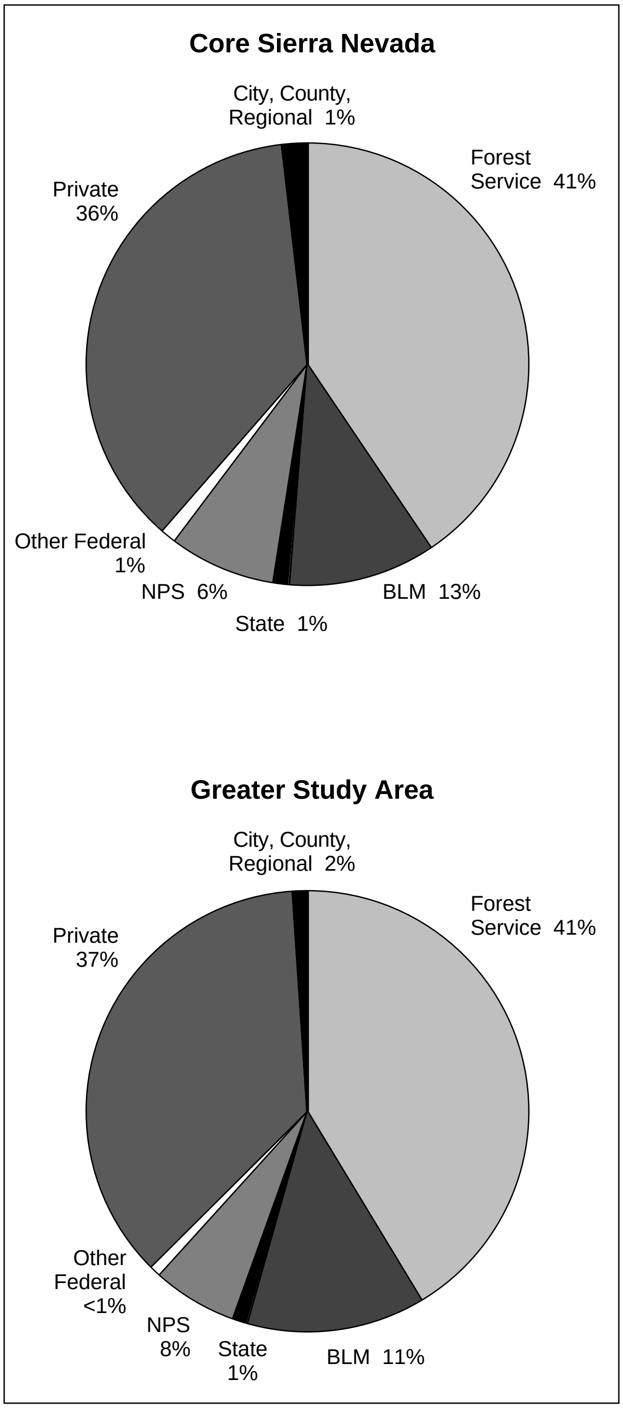

FIGURE 1.7

Sierra Nevada ownership, percentage of land within the core Sierra Nevada ecoregion, and percentage within the greater study area. (From volume II, chapter 23.)

The Sierra Nevada core area includes 20,663,930 acres. Of this, 36% is private. About two-thirds of the land area is publicly owned (figure 1.7). Most of that is national forest (U.S. Forest Service). Bureau of Land Management (BLM) is the second largest category of public land. The National Park Service (NPS), the state of California, and local jurisdictions administer smaller pieces within the SNEP study area (table 1.1). Most of the high elevations throughout the Sierra are public (see back cover), as are large proportions of the eastern Sierra. Public lands extend to middle elevations on the west side, with large areas of intermixtures of private and public sections (“checkerboard”) in the northern half, which track areas of early railroad crossings of the Sierra Nevada. Much of the large private forest company land derives from acquisitions originating from these early railroad land grants. South of the central western Sierra Nevada, fewer large blocks or intermixtures of private land occur at middle elevations. Below about 3,000 feet in the western Sierra, private lands predominate.

Reserve areas account for 21% of the Sierra Nevada, as indicated in table 1.1.

TABLE 1.1

Areas of designated biological reserves in the SNEP core study area.

Public/Private Ownership	Acres (Subtotal)	Acres (Total)
Private Reserves		31,340
Nature Conservancy reserves	31,340	
State of California		144,675
Ecological reserves	2,090	
State parks and reserves	28,837	
Wildlife areas	113,748	
Federal		4,282,204
Bureau of Land Management		
Areas of Critical Environmental Concern and Wild and Scenic Rivers	208,550	
Wilderness Areas	306,535	
Fish and Wildlife Service	1,129	
National Park Service		
Devils Postpile National Monument	806	
Lassen Volcanic National Park	37,979	
Sequoia and Kings Canyon National Parks	861,077	
Yosemite National Park	746,121	
Forest Service		
Research Natural Areas	45,617	
Special Interest Areas	54,916	
Wild and Scenic Rivers	34,055	
Wilderness Areas	1,985,419	
Total reserve areas		4,458,219

Population growth and development bring more people into the region, increasing not only the demand for services but also the diversity of values and issues influencing management of the range. The creation of markets for values and benefits that heretofore have been allocated by right or administrative arrangement—water is the preeminent example—upsets many existing arrangements and creates the need for different types of institutions. Interagency and intergovernmental cooperation blurs lines of authority and blunts institutional prerogative but may allow movement in arenas currently stymied by gridlock. Grassroots activism creates new institutions, which compete with existing ones for legitimacy and authority. These driving forces interact in different ways in different regions of the Sierra and force the evolution of institutions in the range.

SNEP owes its existence to the desire of Congress to search for policies and institutions that can transcend their "ecosystem component" status to perceive the Sierra Nevada as a set of ecosystems with links to stakeholders within and outside the range, and to manage both extraction and reinvestment to ensure the long-term persistence of the ecosystem and the people who depend upon it.

THE SIERRA NEVADA OF THE FUTURE

The images of the Sierra Nevada—snapshots from the past, words and maps from SNEP, mental images of a mountain range—reveal in sketch the unfolding process that has shaped Sierra Nevada ecosystems. Our view of the Sierra is flawed if we consider today's ecological or social environment to be stable: The old-growth forests we study today developed in a different environment from our current one and are headed into a different future. Many of the forests that we now measure and manage originated under an anomalously wet climate. The water systems we have developed are based on predictions of flow derived from this unusually favorable period. Snapshots of the present may give us misleading pictures of what is needed to support a full range of biotic and human systems in the near and distant future.

If there is natural environmental change, does this give license for humans to act however they like in ecosystems? If ecosystems are always changing, why should it matter if we retain the diversity and function of any specific time and place? It matters because both the *rate* and the *direction* of change in natural systems are extremely important to ecosystem sustainability. Plants and animals, and the ecosystems they compose, evolve and adapt to the gradual pace of most environmental change, that is, they produce the successors who are able to survive and prosper. Humans may make conscious decisions to alter the rate and directions of ecosystem change. The important consideration is that we make these decisions with knowledge of potential consequences. As we consider limits to change and tease out the practical meaning of sustainability, we are best prepared when we understand the context of change in the Sierra Nevada.