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Status of Rare and Endemic Plants

ABSTRACT

The Sierra Nevada represents nearly 20% of the California land base yet contains over 50% of the state's flora. Approximately 405 vascular plant taxa are endemic to the Sierra Nevada. Of this total, 218 taxa are considered rare by conservation organizations and/or state and federal agencies. In addition, 168 other rare taxa have at least one occurrence in the Sierra Nevada. Five monotypic genera are endemic to the Sierra Nevada *(Bolandra, Carpenteria, Orochaenactis, Phalacoseris,* and *Sequoiadendron).* Information on rarity and endemism for lichens and bryophytes for the Sierra Nevada is very speculative and fragmentary due to limited fieldwork and the small number of available collections. Two mosses are endemic to the Sierra Nevada. Parameters obtained for each rare and/or endemic taxon include habitat type and distributions by county, river basin, and topographic quadrangle. Distribution information for many taxa remains incomplete based on limited field studies and vouchered specimens, especially in the more unroaded and rugged areas of the Sierra Nevada. Rare and endemic species are not evenly distributed throughout the Sierra Nevada. The Kern, Kings, Merced, San Joaquin, Tuolumne, and Feather River Basins contain the largest concentrations of rare and endemic taxa in the Sierra Nevada. For the eastern slope of the Sierra Nevada, the Owens River Basin is rich in species composition as well as rare and endemic taxa. Of the three geographical subunits, the northern, central, and southern Sierra, the southern Sierra is extremely rich in endemics, rare species, and total floristic composition. Adverse impacts to some Sierran rare plants are occurring along the western fringe of the range adjacent to the Central Valley, where conversion of lands to agriculture and urbanization may greatly restrict or alter essential habitat for some Sierran endemics and/or rare species.

INTRODUCTION

For more than 100 years, the flora of the Sierra Nevada has fascinated botanists even beyond the borders of the United States. Visions of Yosemite, giant sequoias, and extensive mixed conifer forests have added to an awareness of this magnificent mountain range. The Sierra Nevada, part of the California Floristic Province, is characterized by high rates of plant endemism (Stebbins and Major 1965; Raven and Axelrod 1978; Messick 1995). For most of this century, plant collecting and floristic research remained the pursuits of professional botanists with ties to major scientific and educational centers (Shevock and Taylor 1987). Floristic studies have as one of their primary goals documentation of all the taxa (species, subspecies, varieties) for a particular geographic region and determination of their distribution and abundance within that study area (Palmer et al. 1995). Rare, endemic, and disjunct taxa have a special place in such studies because they contribute to the diversity and uniqueness of a flora.

Remarkably, the Sierra Nevada lacks a comprehensive floristic treatment. Portions of the range are covered by a great variety of floristic studies, ranging from detailed floras to florulas and checklists. Floristic studies generally fall into four categories: county floras (Clifton 1994; Oswald 1994; True 1973; Twisselmann 1967), floristic studies by watershed (Henry 1994; Lavin 1983; Palmer et al. 1983; Savage 1973; Shevock 1978; Smith 1973, 1983; Taylor 1981), studies based on park or preserve boundaries (Gillett et al. 1961; Knight et al. 1970; Potter 1983; Pusateri 1963; Rice 1969; Showers 1982), and studies by specific topographical features and habitats (Forbes et al. 1988; Howell 1951; Hunter and Johnson 1983; Sharsmith 1940; Smiley 1921; Tatum 1979; Williams et al. 1992).

Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996.

Much acreage remains in the Sierra Nevada that is not botanically surveyed or systematically vouchered, especially in unroaded or relatively rugged areas.

With the passage of the federal Endangered Species Act of 1973 (ESA, as amended) came a distinct shift in plant collecting and subsequent conservation efforts toward a focus on those taxa believed to be candidates for threatened or endangered status. These distribution data were increasingly obtained by plant enthusiasts, botanical consultants, and various state and federal agency botanists rather than traditional academic botanists with ties to major educational institutions (Ertter 1995; Shevock and Taylor 1987). Initially, the information available to determine which taxa were in fact rare and/or endemic was fragmentary, with most information restricted to a handful of herbarium specimens (Powell 1974). With efforts directed at rediscovery of old herbarium records, along with systematic and focused fieldwork to document new occurrences, understanding of the distribution of rare and endemic species has greatly improved (Smith et al. 1980; Smith and York 1984; Smith and Berg 1988; Skinner and Pavlik 1994).

Floristic inventories are becoming ever more important as a method of documenting the plant diversity of a specific land base. However, many of the currently available floras and checklists lack citations of representative vouchered specimens to validate each of their entries. Without references to vouchered plant material deposited in major herbaria, these floras and checklists have reduced value because material on which the catalogue of names is based is not available for future study and taxonomic review (Palmer et al. 1995; Ferren et al. 1995). Of course, many floras are based on a review of herbarium records, but again, representative specimens are rarely cited in the publication of floristic studies. Wilken (1995) provides a convincing case for continued floristic studies in California that emphasize comparative analyses based on biogeographical patterns of diversity at both regional and local levels.

It may come as a surprise to many not familiar with the California flora that vascular plants are still being discovered and described as new to science for the Golden State. The majority of these newly published species are both endemic and rare. The period 1968–86 yielded over 220 newly described vascular plant taxa for California; sixty-five of these occur in the Sierra Nevada (Shevock and Taylor 1987). With publication of The Jepson Manual (Hickman 1993), ongoing floristic analysis by Shevock and Taylor (in preparation) will document that since 1986 this trend of discovery and publication of new vascular plant taxa continues. The southern Sierra Nevada in particular, along with other areas of carbonate and serpentinite geology, remains an area of the state worthy of continued floristic study and research (Norris 1987; Shevock 1988). During the past few years several new species have been discovered in the Sierra Nevada. Because many of these new taxa are rare and/or endemic to a single river basin, they are incorporated in this assessment with the specific epithet "sp. nov.," "ssp. nov.," or "var. nov." until the names have been effectively published according to the International Code of Botanical Nomenclature.

This assessment was developed to determine the distribution of both endemic and rare plant taxa in the Sierra Nevada, primarily at the river basin level. For the core study area, the Sierra Nevada was divided into twenty-four river basins (figure 24.1) ranging in size from the Feather at 971,611 ha (2,399,878 acres) to the Calaveras at 94,018 ha (231,285 acres). River basin boundaries are useful because they are easy to determine both in the field and on maps, in contrast to political boundaries such as counties, forests, and parks, which have the potential to change through time. Furthermore, river basins provide a biogeographical context in which to evaluate floristic components such as rare and/or endemic species. Size, elevation range, geology and soils, vegetation types, and geographical location of each river basin are factors used to speculate why river basins vary widely in total number of taxa, including rare and endemic species. As a general overview, the northern Sierra is predominantly volcanic in origin, and the central and southern Sierra are both mainly granitic, with several areas of metamorphic and metasedimentary parent materials.

Lum (1975) may have been the first to address broad patterns of vascular plant species diversity based on A California Flora and Supplement (Munz and Keck 1959; Munz 1968). Lum also evaluated the distribution of all taxa displayed in this floristic treatment at the county level and further divided the counties to address physiographic provinces. This approach subdivided California from fifty-eight counties into ninety-four geographical units for her diversity analysis of the flora. Lum evaluated each entry in the flora (5,902 taxa) in a database with several parameters obtained per taxon. Although this approach provided many insights into the distribution and diversity within the flora, it appears that Lum made several "taxonomic decisions" by aggregating varietal and subspecific taxa to the species level, which reduced the number of highly localized endemics that could be analyzed. Nonetheless, Lum's contribution toward an understanding of vascular plant diversity in California is noteworthy. Walker (1992) added to the study of plant diversity in the Sierra Nevada by analyzing species richness and variation by plant community. Both of these studies were used to evaluate distribution patterns for rare and/or endemic vascular plants within the study area.

Nonvascular plants for this study include both lichens and bryophytes. Lichens are actually not plants but photosynthetic associations consisting of dense populations of green algae or cyanobacteria within the fungal tissue (Ahmadjian 1995). The process of this unusual association forms a "plant body" technically called a thallus, which has little resemblance to either an alga or a fungus (Hale and Cole 1988). Botanists and ecologists have historically treated lichens as a group of nonvascular plants primarily because lichens can colonize

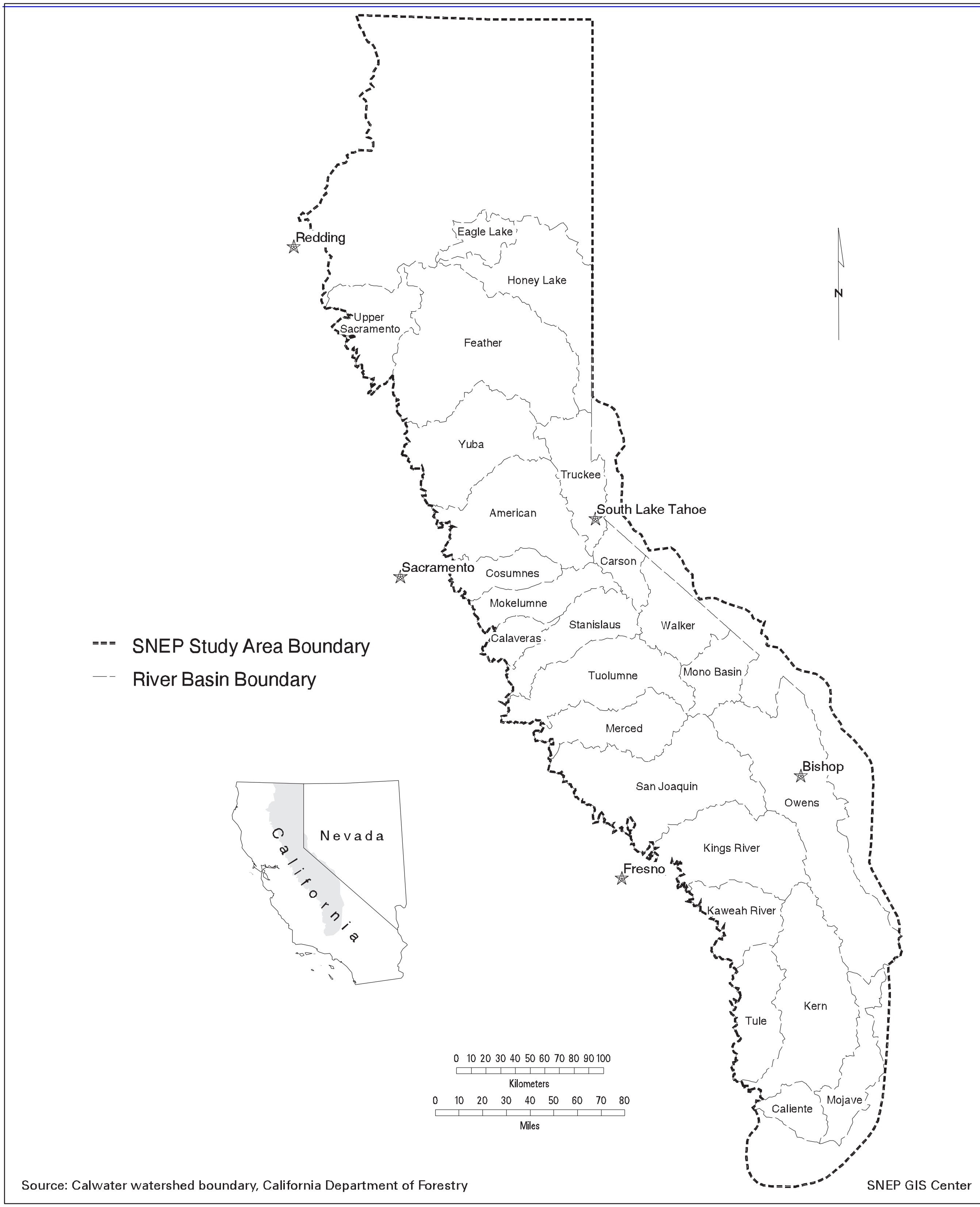

FIGURE 24.1

SNEP study area with river basin boundaries.

much of the terrestrial surface of the earth and can resemble a cover type of vegetation similar to bryophytes.

The nonvascular plant data were significantly more difficult to analyze. First, no comprehensive lichen or bryophyte flora is available at this time for California, let alone for the Sierra Nevada. Moreover, the lack of general floristic works for lichens and bryophytes greatly hinders analysis to determine rarity and endemism (Andrus 1990; Henderson 1981). Distribution information, as documented by herbarium specimens, is limited for lichens and bryophytes compared with that for vascular plant material. Lichens and bryophytes occurring in the Sierra Nevada are considerably less collected than those of coastal California. Therefore, at present, all the distribution information on rare and/or endemic species of lichens and bryophytes in the Sierra Nevada must be viewed as extremely provisional.

Endemism

Endemism (taxa restricted to a given area) is one component of biodiversity that particularly interests biologists and plant enthusiasts (Kruckeberg and Rabinowitz 1985; Stebbins and Major 1965). Plants can be endemic to all kinds of features and geographic areas, ranging from mountain peaks, mountain ranges, river basins, and watersheds to political boundaries such as parks, preserves, counties, and states and physical attributes like soils and rock types. Endemism is an important concept in conservation biology. Endemic species must rely exclusively for their long-term viability and continued existence on the management of the geographical area to which they are restricted. Endemism is one of the criteria used to set priorities for species conservation efforts.

Generally, the smaller the area under study, the fewer endemic species it is likely to contain. For example, nearly 30% of the California flora is endemic to the state (Raven and Axelrod 1978), but the smaller Sierra Nevada has a 15% endemism level. Two factors are key in explaining the lower percentage of endemics occurring in the Sierra Nevada. First, this mountain range is only one-fifth the size of California, and as mentioned earlier, geographic size is one factor affecting endemism. The second factor, and in this case the more important one, is that there are few topographic barriers between the Sierra Nevada and other areas that have similar climate, vegetation, and soils. This factor results in a reduced percentage of endemism. Therefore, the Sierra Nevada is species-rich in relation to its size and contains over 50% of the flora for the state. The Sierra Nevada is predicted to be the most floristically diverse area for its size in all of North America north of Mexico. The other species-rich area is also part of the California Floristic Province. The northwestern California and southwestern Oregon area is expected to contain 3,500 taxa with 281 endemics (Smith and Sawyer 1988).

The boundary selected for this study affects which species are viewed as "endemic" to the Sierra Nevada. The boundary used follows the primary river basins as identified in the SNEP Progress Report (Sierra Nevada Ecosystem Project 1994), creating an area that is somewhat larger than what would have been used if floristic elements were the overriding criteria. For example, the boundary in the northern Sierra contains the river basin divide formed on Lassen Peak, whereas many botanists consider Lassen Peak as the southern end of the Cascade Range and would place the northern boundary of the Sierra Nevada slightly northwest of the canyon of the North Fork of the Feather River (Hickman 1993). The entire Feather River Basin remains in this assessment. Along the western slope, a band of gently rolling hills provides an elevational break separating the Sierra Nevada from the Central Valley. The southern Sierra extends along the boundary of Caliente Creek watershed (next to California Highway 58) in the northern Tehachapi Mountains. This boundary also is similar to that expressed by Hickman (1993). The eastern boundary of the Sierra Nevada presents several floristic complications, because the river basin boundaries extend eastward beyond the Sierran escarpment, and no matter where one draws the line, the decision affects the statistical analysis of rarity and endemism within the Sierra. On the eastern slope, especially in the Owens and Mojave River Basins, the boundary selected parallels the escarpment along California Highway 14 and US 395 and extends northeast to incorporate the Mono Basin to the California-Nevada state line. A small portion of the state of Nevada is also incorporated into the Sierra Nevada from Topaz Lake north and west of US 395 to Hallelujah Junction.

Rarity

Another aspect of biodiversity relates to the concept of rarity. Much literature has been devoted to this subject (Harper 1981; Fiedler 1986, 1995; Fiedler and Ahouse 1992; Skinner and Pavlik 1994; Stebbins 1978a, 1978b, 1980), and therefore it will not be elaborated further here. Seven types of rarity, based on different combinations of geographic range, habitat specificity, and local population size (Rabinowitz 1981) are all well represented in the Sierra Nevada. Knowledge of different rarity patterns is essential in determining the kinds of conservation activities necessary to prevent species extinction or localized extirpations (Lesica and Allendorf 1992, 1995; Reveal 1981; Schemske et al. 1994). Few plant taxa within the Sierra Nevada appear to be threatened or endangered specifically on account of human actions either through restriction of overall population numbers or restriction of historic range. However, anthropogenic activities during this century have clearly impacted many rare plants. For some taxa, the cumulative impacts have been severe, and just a handful of occurrences remain. Three species are believed to be already extinct in the Sierra Nevada. Monardella leucocephala, last seen in 1941 at the extreme western boundary of the Sierra Nevada in Merced County, is presumed to be extinct. This extinction is attributed to human activities this century that changed valley grassland habitat to agricultural land (Skinner and Pavlik 1994). Two other species, also in the central Sierra Nevada, are viewed as possibly extinct: Erigeron mariposanus, last seen in 1900, and Mimulus whipplei, last seen in 1854. Erigeron mariposanus was collected several times between 1892 and 1900. It is suspected that this species was restricted to a specialized habitat that may have been altered this century. Mimulus whipplei was described from a single herbarium collection. Botanists are uncertain whether it merely represents an aberrant collection of a more widespread species or actually warrants taxonomic recognition. Focused surveys and field studies may yet rediscover these presumed extinct taxa (Skinner et al. 1995).

Another problematic species is Sedum pinetorum. This species appears to be a good taxon. In 1925, Jepson thought it was so different from Sedum (in having solitary flowers and tuberous roots) that he published the monotypic genus Congdonia to accommodate it. This taxonomic circumscription was carried forward by Munz and Keck (1959). Congdonia, however, proved to be an invalid name due to prior use, and this taxon returned to the genus Sedum. The concern, therefore, lies not with its taxonomic distinctiveness but rather its presumed location. Collected in 1913 by Katherine Brandegee and described in 1916 by T. S. Brandegee, Sedum pinetorum is believed to have been collected along the eastern slope of the Sierra Nevada in the vicinity of Mammoth, Mono County. However, the type population has never been relocated, nor has the species been collected since.

Based on examination of seeds within the fragment packet with the type specimen (at the University of California, Berkeley collection), there is speculation that the specimen probably came not from the Sierra Nevada but more likely from Mexico (Moran 1950). Sedum pinetorum was subsequently deleted from the third edition of the California Native Plant Society Inventory (Smith and Berg 1988), the California Natural Diversity Database, and most recently The Jepson Manual (Hickman 1993), even though no one has found Sedum pinetorum in Mexico either. I included the species in this assessment until another collection of Sedum pinetorum becomes available to resolve this mystery. Again, focused surveys may yet rediscover this inconspicuous plant of the eastern Sierra Nevada in the Mammoth area.

Gaps and Caveats

Clearly there are gaps in the known distribution information of many Sierran rare and endemic plants. One factor may be that some river basins have been explored more systematically than others, primarily as a function of access by roads. This assessment acknowledges that the data sets are far from complete. It is hoped this assessment will encourage general botanical collecting (especially at the river basin level) with the objective of filling in the gaps in distribution data with vouchered material and perhaps discovering plants that have heretofore remained undescribed.

The perceived rarity or endemic status for some rare and/or endemic Sierran taxa is expected to change as systematic fieldwork continues. Also, further taxonomic studies (mainly detailed monographic works) should clarify some of the taxonomic uncertainties that currently exist (Skinner et al. 1995). For rare taxa, this study follows the taxonomic circumscriptions used by Skinner and Pavlik 1994 and California Department of Fish and Game 1995 and does not dismiss difficult taxa or those submerged in more recent floristic treatments (Hickman 1993; Skinner and Ertter 1993). This approach and rationale is based in part on my own field experience, in which ecological differences and growth forms may not readily be observed solely from a review and evaluation of an herbarium specimen.

METHODS

For the analyses reported here, a database was developed to query various Sierra Nevada rare and endemic plant records. The data fields are divided into four broad categories: taxonomic, rarity, endemism, and distribution information. Taxonomic fields include plant code, vascular or nonvascular, family, genus, and specific and infraspecific epithets. Rarity fields include federal listing, state listing, California Natural Diversity Database list, California Native Plant Society list, and U.S. Fish and Wildlife Service list. Endemism fields include Sierra Nevada rare, Sierra Nevada endemic, and plants rare but located beyond the Sierra Nevada. Distribution fields include counties, river basins, habitat types, and topographic quadrangles.

For California rare plant species, the California Native Plant Society (CNPS) publication Inventory of Rare and Endangered Vascular Plants of California (Skinner and Pavlik 1994) was the primary reference consulted, together with data maintained by the rare plant component of the California Natural Diversity Database (CNDDB), California Department of Fish and Game (1995). Rare plants for the state of Nevada were obtained from the Nevada Heritage Program (Morefield and Knight 1991; Morefield 1994). For each rare and/or endemic taxon, the range of distribution by primary river basin within the Sierra Nevada was plotted by analyzing these data, including the analysis conducted by Lum (1975). For plants that are endemic to the Sierra Nevada but not rare or endangered, these data were laboriously gathered by species distribution information in A California Flora (Munz and Keck 1959) and Supplement (Munz 1968) plus taxa newly described since 1968 (Shevock and Taylor 1987). The Jepson Manual (Hickman 1993) was also analyzed, by Dean Taylor, for additional rare and/or endemic taxa occurring in the Sierra Nevada. I obtained additional distribution information for nonrare Sierran vascular plant endemics by reviewing numerous floras, florulas, and checklists (both published and unpublished) within the

Sierra Nevada. An extensive herbarium review to obtain supplemental distribution information for vascular plants was not conducted as part of this study.

For this study, lichen and bryophyte data sets were provided by leading professional authorities in these two fields of taxonomic study. Bruce Ryan at Arizona State University, Tempe, offered field knowledge and expertise on Sierran lichen distributions, and Daniel Norris at the University of California, Berkeley, provided the data sets for Sierran rare and endemic bryophytes. Selected California herbaria with important lichen and bryophyte collections (California Academy of Sciences [CAS], San Francisco State University [SFSU], and University of California, Berkeley [UC]) were visited to obtain distribution information necessary to plot occurrences within Sierran river basins.

RESULTS AND DISCUSSION

Nonvascular Plant Taxa

Of the nearly 3,330 species of lichens known to occur in the continental United States and Canada (Egan 1987), over 1,000 species have been documented to occur in California (Hale and Cole 1988; Tucker and Jordan 1978). Knowledge of lichen distributions is rather fragmentary compared with that of vascular plants. There are relatively few lichen floristic studies within the Sierra Nevada. In these available floras and checklists, 207 lichens have been documented for a portion of Tulare County (Smith 1980; Wetmore 1985, 1986; Sequoia National Park 1995), and 85 lichen taxa were reported from a mixed conifer forest at Calaveras Big Trees State Park (Pinelli and Jordan 1978). Herbert and Meyer (1984) documented 76 lichen species within a small area dominated by a blue oak woodland at the U.S. Department of Agriculture San Joaquin Experimental Range in Madera County. For the east slope of the Sierra Nevada, Herre (1911) reported 59 lichen species in the vicinity of Reno, of which he described two species as new. Ryan and Nash (1991) collected over 100 species in the Eastern Brook Lakes watershed in Inyo County, of which 30 species were new lichen records for California.

From the data sets that are at present available, it appears that no lichens currently can be considered endemic to the Sierra Nevada. However, endemism cannot be determined with any reliability for lichens in the Sierra Nevada primarily because so few lichenologists are available to conduct taxonomic work or study them systematically. For example, there are several crustose lichens, such as Lecidea truckeei, that may actually be rare, but this group is taxonomically very difficult to identify. Many crustose lichens may have much wider distributions than is currently understood, while others, perceived to be more widespread, could indeed be rare or endemic. At this time, however, it is not possible to determine accurate distributions, because the majority of specimens in most lichen herbaria have not yet been properly identified or are labeled only to the genus level. This situation is even more acute for the crustose group of lichens (Ryan 1995a).

Lichens display different rarity and distribution patterns than those commonly observed in vascular plants. Many lichens have wide-ranging distributions in North America but within their geographic range display a pattern of very localized occurrences restricted to specific habitats and/or narrow microenvironments. Rarity in lichens is therefore characterized by small, disjunct populations. The species richness of the lichen flora is greater in the maritime and coastal-fog-influenced areas of California (Hale and Cole 1988). The drier interior of the state, a Mediterranean climate with continental influences, has a different assemblage of lichens, with more crustose lichen taxa and fewer foliose and fruticose lichen taxa.

For this assessment, eight lichen species are considered rare in the Sierra, and two of these represent the only known occurrences in California: Dermatocarpon moulinsii, Dimelaena oreina (atypical forms in the Sierra), Hydrothyria venosa, Hypogymnia metaphysodes, Rhizoplaca glaucophana, Rhizoplaca marginalis, Umbilicaria torrefacta, and Waynea stoechadiana (Ryan 1995). Hydrothyria venosa is very unusual as it is the only aquatic foliose lichen species. It is restricted to rocks in clear, unpolluted streams. Within California, this species is currently known from only a few streams, ranging from Calaveras Big Trees State Park, Calaveras County, south to a tributary of the Kern River Basin in Sequoia National Forest, Tulare County.

Lichens as a taxonomic group are often used in air-quality monitoring studies because many species are sensitive to air pollution (Ryan 1990b). Air-quality degradation in the Sierra Nevada has adverse effects on some lichens. A few species may become extirpated in portions of their range within the Sierra Nevada if air quality continues to deteriorate. Extirpations of lichens in other mountains of California have already occurred. In their study of the San Gabriel and San Bernardino Mountains, Sigal and Nash (1983) were not able to relocate eight species of lichens that were collected there in conifer forests by Hasse in his Lichen Flora of Southern California published in 1913. Three Sierran baseline monitoring studies of lichens and air quality have been conducted. Ryan (1990a, 1990b) identified over 90 lichen species for both the Desolation Wilderness in the Lake Tahoe area and the Emigrant Wilderness, Stanislaus National Forest; the third study, by Wetmore (1985, 1986), obtained 207 lichens for Sequoia National Park and the Grant Grove section of Kings Canyon National Park.

The bryophytes (mosses, liverworts, and hornworts) are a diverse group of nonvascular plants (Crosby 1980) with nearly 23,000 described species worldwide. In North America, more than 1,220 species have been documented (Schofield 1980). Endemism in bryophytes approaches 23% for North America. For the west coast of North America, Lawton (1971) identified nearly 600 mosses in her treatment of the Pacific Northwest, the largest moss flora of a geographic region within

North America. Bryophyte taxa generally have much wider distribution ranges than vascular plants. Endemism at smaller geographic scales such as the state of California drops markedly (Koch 1950a, 1954).

Though no modern-era (post-1950s) bryophyte flora for California currently exists, such a flora is in preparation by Dan Norris and Brett Mishler at the University of California, Berkeley. Surprisingly, California and the adjacent southwestern United States have the least studied bryophyte floras in North America. At this time, Lawton 1971 and Flowers 1973 are the two floras available to provide identification of Sierran mosses. Based on herbarium records and fieldwork to date, the California bryophyte flora contains 508 species of mosses, 116 species of liverworts, and 6 species of hornworts (Mishler 1995). This record shows a significant increase in the number of taxa in California over earlier checklists of 317 mosses by Koch (1950) and 86 liverworts by Howe (1899). Of the thirty-five thallose liverworts recorded for California by Whittemore 1982, twenty-seven occur in the Sierra Nevada.

Bryophytes are well developed in the Pacific Northwest, especially in the temperate rain forests of Sitka spruce and western hemlock from southern Alaska and British Columbia to the coast redwood zone of northwest California (Lawton 1971). The bryophyte flora for the Sierra Nevada is predicted to be less diverse because this area is significantly more xeric than the Pacific Northwest. Showers (1982) documented 149 moss taxa for Lassen Volcanic National Park. Koch (1958) listed 72 mosses for the Harvey Monroe Hall Research Natural Area and vicinity toward Lee Vining along the eastern escarpment of the Sierra Nevada in Mono County. However, too few studies have been conducted to allow comparisons between the Sierra Nevada and the overall California bryophyte flora. In fact, Thiers and Emory (1992) listed the sixteen master's theses on California bryophytes for 1969–90, and only one floristic study was conducted within the SNEP boundary, the master's thesis work by Showers completed in 1978 and subsequently published in Showers 1982. There appear to be no other bryophyte floras for any smaller geographic areas within the Sierra Nevada.

Bryophytes share many of the distribution patterns observed in lichens. They tend to be highly localized to specific microenvironments defined by factors related to water availability, temperature, light, and substrate chemistry (Mishler 1995). For this assessment, seventeen mosses are considered rare in the Sierra Nevada (Norris 1995a, 1995b; Showers 1995). Grimmia hamulosa and Orthotrichum spjutii are endemic to the Sierra Nevada. Mielichhoferia tehamensis is endemic to Lassen Volcanic National Park. The remaining fourteen mosses, which are distributed beyond California, are Andreaea nivalis, Bruchia bolanderi, Campylium stellatum, Distichium inclinatum, Grimmia moxleyi, Hydrogrimmia mollis, Lescuraea pallida, Mnium arizonicum, Myurella julacea, Orthotrichum euryphyllum, Polytrichum sexangulare, Racomitrium hispanicum, Tayloria serrata, and Tortula californica. Several of these mosses are Holarctic (northern hemisphere) in distribution or have widely scattered occurrences in North America. No liverworts or hornworts are considered rare or endemic to the Sierra Nevada.

Based on the distribution ranges of all Sierran plant endemics, clearly Orthotrichum spjutii is the rarest of all. This moss is known from a single rock face in the spray of a waterfall on the eastern slope of the central Sierra within the Walker River Basin. Mielichhoferia tehamensis occurs in the northernmost portion of the Sierra Nevada, with most occurrences within the headwaters of the Feather River Basin. This rare and endemic moss is restricted to deeply shaded, north-facing, steep canyon walls where winter snows remain well into July (Showers 1982).

One of the principal findings of this assessment is that there is a great need for systematic collecting and taxonomic study of lichens and bryophytes to aid in understanding species endemism, rarity, and distribution. Besides the small number of specimens available for study, there are also few botanists trained to study lichens and bryophytes. The importance of lichens and bryophytes to ecosystem function has been largely overlooked by many conservation biologists (Ahmadjian 1995; U.S. Forest Service 1995).

Vascular Plant Taxa

The Sierra Nevada plant database developed for this assessment contains 572 vascular plant entries, of which 383 taxa are being tracked by the CNDDB (California Department of Fish and Game 1995) and by the CNPS (Skinner and Pavlik 1994). Rare plants comprise 386 taxa, of which 168 extend beyond the Sierra Nevada. There are 405 vascular plant taxa endemic to the Sierra Nevada. Of this total, 223 are considered rare, and the remaining 182 plant taxa appear to be distributed across the landscape in such numbers and occurrences that their likelihood of their becoming rare, threatened, or endangered is low at this time. The distributions of these taxa by river basins provides a basis for analysis and interpretation of the flora, species richness, and diversity, with a focus on both rarity and endemism. Forty Sierran endemics are widespread, occurring in all three geographical subdivisions (northern, central, and southern). Another 133 endemic taxa occur in two subdivisions. Within these subdivisions, 55 taxa are endemic to the northern Sierra, 53 are endemic to the central Sierra, and 124 are endemic to the southern Sierra.

California has twenty-six endemic genera of vascular plants (Howell 1957; Raven and Axelrod 1978). The Sierra Nevada contains five endemic genera that are also monotypic. These were all described as "new to science" as a result of early botanical explorations in the Sierra Nevada during the middle to late 1800s. Sequoiadendron and Carpenteria were described in 1853, Bolandra and Phalacoseris in 1868, and Orochenactis in 1883. There have been no new vascular plant genera recognized in California since Dedeckera was discovered in the adjacent White Mountains in 1976. The probability that a new vascular plant genus will be discovered in the Sierra Nevada seems unlikely based on the level of fieldwork conducted in this mountain range during the past hundred years.

Of the seven river basins within the boundary of the northern Sierra Nevada, those of the Feather and American Rivers have the greatest number of taxa, including endemic and rare taxa (table 24.1). Of the 140 study taxa located within the Feather River Basin, 79 are endemic to the Sierra Nevada, and 95 are rare. The large number of rare taxa is primarily a result of the location of this river basin adjacent to the Cascade Range; several rare plants from the Klamath Mountains and Cascade Range reach their southernmost distribution limits within the Feather River Basin. Based on this study, eleven taxa are endemic to this river basin. The American River Basin shares a similar pattern except that it has a higher proportion of Sierran endemics, but only seven taxa are endemic to this river basin. The Truckee River Basin has the second highest number of endemics, with ten for the northern Sierra, of which two are endemic to the portion of the range in Nevada.

The central Sierra, which contains ten river basins, displays a completely different pattern from the one observed in the northern Sierran river basins (table 24.1). Three adjacent river basins (Tuolumne, Merced, and San Joaquin) are nearly identical in total numbers of taxa, Sierran endemics, and rare elements. They also share high numbers of endemic and rare taxa as compared with the other river basins within the central Sierra Nevada. For taxa that are endemic to a single river basin, the San Joaquin leads, with six taxa, and the Merced and Tuolumne have four each.

TABLE 24.1

Distribution of rare and endemic plants by Sierran river basins.

River Basin[a]	Number of Taxa from Database	Sierran Endemics	Rare Taxa	Endemic to River Basin
Northern Sierra				
American	104	85	46	7
Eagle Lake	5	1	5	0
Feather	140	79	95	11
Honey Lake	20	6	20	1
Truckee	49	38	29	10
Upper Sacramento	46	12	42	2
Yuba	91	69	45	2
Central Sierra				
Calaveras	63	61	16	1
Carson	22	15	12	0
Consumnes	72	66	21	0
Merced	153	140	53	4
Mokelumne	90	80	31	2
Mono Lake	65	45	32	1
San Joaquin	149	135	57	6
Stanislaus	100	93	31	0
Tuolumne	152	133	59	4
Walker	33	18	23	4
Southern Sierra				
Caliente	29	22	18	1
Kaweah	112	104	37	3
Kern	200	167	91	22
Kings	160	150	56	6
Mojave	28	19	21	4
Owens	104	71	59	8
Tule	87	83	31	2

[a]Several river basins extend beyond the study area boundary. Rare and endemic species are recorded only for those taxa within the study area.

The southern Sierra, with seven river basins, has a greater number of taxa, Sierran endemics, and rare elements than the northern or central Sierra (figure 24.1). The southern Sierra contains the highest elevation within the Sierra Nevada (the Mount Whitney area), and at the same time the range is narrower in width and thus steeper than the central and northern Sierra. This portion of the Sierra Nevada contains extensive alpine and subalpine areas that provide habitat for many Sierran endemic and rare taxa (Stebbins 1982). The greater aridity of the southern Sierra Nevada is also part of the reason for the high number of endemics compared with the northern Sierra. The Kern River Basin has 200 study taxa, of which 167 are endemic to the Sierra Nevada and 91 are rare. This single river basin has twenty-two plants endemic within its boundary; the Owens River Basin has eight endemics, and the Kings River Basin has six. The Owens River Basin, which contains the steep and rugged east face of the Sierra Nevada, dominates transmontane river basins in total taxa, Sierran endemics, and rare elements. Table 24.2 provides the catalogue of taxa endemic to individual river basins in the Sierra.

The geographic unit traditionally used to evaluate plant distributions in California is the county (Munz and Keck 1959; Skinner and Pavlik 1994). Table 24.3 displays rare and endemic plant information by county in a format suitable for comparison with river basins (table 24.1). Though the boundaries of the northern, central, and southern Sierra Nevada are altered to follow county lines (figure 24.2), the boundary differences do not in general alter the overall trends of the data presented. In the northern Sierra Nevada, El Dorado and Plumas Counties contain the greatest number of taxa, Sierran endemics, and rare taxa, and these two counties correspond closely to the boundaries of the American and Feather River Basins. Within the central Sierra Nevada, Mariposa County dominates all categories, followed closely by Madera County. The four counties represented in the southern Sierra Nevada all contain high concentrations of endemic and rare taxa. Tulare and Fresno Counties lead in all categories and are the counties with the largest number of endemics and rare species for the entire Sierra Nevada. Table 24.4 provides the catalogue of taxa endemic to the Sierra Nevada by counties.

The use of topographic quadrangles is another geographic approach for addressing the distribution of species. In this assessment, only rare taxa were recorded to the topographic quadrangle level, based on data obtained from Skinner and Pavlik (1994). Data sets for CNPS list 4 taxa (plants of limited distribution) lack quadrangle information. For these taxa, I attempted to review all CNPS and CNDDB manual files to obtain these data sets where available. However, many distribution gaps remain at the quadrangle level for CNPS list 4 plants.

TABLE 24.2

Sierra Nevada endemics at the river basin level.

Northern Sierra Nevada	Central Sierra Nevada	Southern Sierra Nevada
American River Basin	***Calaveras River Basin***	***Caliente Creek Basin***
Ceanothus roderickii	*Mimulus whipplei*	*Clarkia tembloriensis* ssp. *calientensis*
Draba asterophora var. *macrocarpa*		
Galium californicum ssp. *sierrae*	***Merced River Basin***	***Kaweah River Basin***
Lewisia serrata	*Clarkia lingulata*	*Eriogonum nudum* var. *murinum*
Navarretia prolifera ssp. *lutea*	*Eriophyllum congdonii*	*Mimulus norrisii*
Phacelia stebbinsii	*Plagiobothrys torreyi* var. *torreyi*	*Ribes tularense*
Wyethia reticulata	*Viola adunca* var. *kirkii*	
		Kern River Basin
Feather River Basin	***Mokelumne River Basin***	*Abronia alpina*
Astragalus lentiformis	*Eriogonum apricum* var. *apricum*	*Astragalus ertterae*
Astragalus webberi	*Eriogonum apricum* var. *prostratum*	*Astragalus shevockii*
Calamagrostis sp. nov.		*Camissonia integrifolia*
Ceanothus sp. nov.	***Mono Lake Basin***	*Castilleja praeterita*
Clarkia mosquinii ssp. *mosquinii*	*Arabis tiehmii*	*Ceanothus pinetorum*
Clarkia mosquinii ssp. *xerophylla*		*Clarkia xantiana* ssp. *parviflora*
Erigeron lassenianus var. *deficiens*	***San Joaquin River Basin***	*Cordylanthus rigidus* ssp. *brevibracteatus*
Monardella stebbinsii	*Calyptridium puchellum*	*Crythantha incana*
Penstemon personatus	*Collomia rawsoniana*	*Delphinium purpusii*
Sedum albomarginatum	*Erigeron mariposanus*	*Erigeron multiceps*
Senecio eurycephalus var. *lewisrosei*	*Erythronium pluriflorum*	*Eriogonum breedlovei* var. *breedlovei*
	Lupinus citrinus var. *deflexus*	*Eschscholzia procera*
Honey Lake River Basin	*Phacelia ciliata* var. *opaca*	*Galium angustifolium* ssp. *onycense*
Scutellaria holmgreniorum		*Githopsis tenella*
	Tuolumne River Basin	*Heterotheca shevockii*
Truckee River Basin	*Allium tuolumnense*	*Horkelia tularensis*
Arabis rigidissima var. *demota*	*Brodiaea pallida*	*Mimulus microphyllus*
Arabis rigidissima var. *simulans*	*Senecio clevelandii* var. *heterophyllus*	*Mimulus shevockii*
Astragalus austinae	*Verbena californica*	*Nemacladus twisselmannii*
Astragalus whitneyi var. *lenophyllus*		*Streptanthus cordatus* var. *piutensis*
Berberis sonnei	***Walker River Basin***	*Swertia tubulosa*
Elatine gracilis	*Draba incrassata*	
Eriogonum robustum	*Orthotrichum spjutii*	***Kings River Basin***
Ivesia aperta var. *canina*	*Plagiobothrys glomeratus*	*Arabis* sp. nov.
Rorippa subumbellata	*Senecio pattersonensis*	*Cordylanthus tenuis* var. *barbatus*
Tonestus eximus		*Eriogonum nudum* var. *regirivum*
		Gilia australis sp. nov.
Upper Sacramento River Basin		*Heterotheca* sp. nov.
Calystegia atriplicifolia ssp. *buttensis*		*Streptanthus fenestratus*
Rupertia hallii		
		Mojave River Basin
Yuba River Basin		*Chamaesyce vallis-mortae*
Plagiobothrys glyptocarpus var. *modestus*		*Eriogonum kennedyi* var. *pinicola*
Sidalcea stipularis		*Hemizonia arida*
		Lomatium shevockii
		Owens River Basin
		Astragalus sepultipes
		Galium hypotrichium ssp. *inyoense*
		Lomatium rigidum
		Lupinus pratensis var. *eriostachys*
		Penstemon papillatus
		Phacelia inyoensis
		Sedum pinetorum
		Sidalcea covillei
		Tule River Basin
		Clarkia springvillensis
		Dudleya cymosa ssp. *costifolia*

Rare plants were documented on 623 of the 7.5-minute topographic quadrangles covering the Sierra Nevada. Figure 24.3 provides a visual representation of the concentration and distribution of rare taxa ranging from one to fifteen rare plants per quadrangle. There are several areas throughout the Sierra Nevada where concentrations or ensembles of rare and endemic species are located. Quads with five or more rare plants generally represent the presence of an ensemble area. Many of these ensembles are located on unusual substrates or soils, occur in areas with high plant species diversity, or occur in uncommon habitats or vegetation types. Examples of ensemble areas include the Ione Formation in Amador County, the Red Hills in Tuolumne County, the serpentinites of the Feather River Canyon in Butte and Plumas Counties, and the sandy granitic meadow borders of the Kern Plateau in Tulare County.

TABLE 24.3

Distribution of Sierran rare and endemic plants by county.

County[a]	Number of Taxa from Database	Sierran Endemics	Rare Taxa	Endemic to County
Northern Sierra				
Butte	89	58	52	6
El Dorado	103	89	45	5
Lassen	34	6	34	0
Nevada	75	59	55	4
Placer	86	71	35	0
Plumas	104	61	66	5
Shasta	29	3	27	0
Sierra	53	36	34	1
Tehama	31	3	30	0
Yuba	34	29	11	0
Central Sierra				
Alpine	36	24	19	2
Amador	77	72	23	2
Calaveras	83	80	23	1
Madera	131	123	37	1
Mariposa	154	143	55	6
Merced	8	5	6	0
Mono	103	60	65	6
Tuolumne	154	135	61	7
Southern Sierra				
Fresno	176	160	70	7
Inyo	113	81	56	6
Kern	111	84	71	17
Tulare	215	190	98	21

[a]Several counties extend beyond the study area boundary. Rare and endemic species are recorded only for those taxa within the study area.

Table 24.5 provides another perspective for assessment of speciation and distribution patterns. The genera with the largest number of rare and/or endemic taxa in the Sierra Nevada are Eriogonum (27), Astragalus (22), and Mimulus (19). When compared with the largest genera within the California flora (Smith and Noldeke 1960; Noldeke and Howell 1960), Eriogonum ranks fifth, Astragalus second, and Mimulus sixth. Astragalus, with over 2,000 species, is well known for its worldwide level of speciation, being among the largest genera of flowering plants. Eriogonum, with approximately 250 species, most of which are in the western United States, is also known for its high number of rare and endemic taxa. Mimulus, with nearly 150 species, has its center of distribution in North America. The Sierra Nevada provides a diversity of habitats in which endemic annual Mimulus species have evolved. The fourth-ranked genus with rare and endemic taxa in the Sierra Nevada is Clarkia (18). With forty-one species, of which thirty-nine occur in California, this genus appears to be speciating into ecological niches, with thirteen taxa being both rare and endemic to the Sierra Nevada. Thirty percent of all taxa that are either rare and/or endemic for the Sierra Nevada are distributed within the eleven genera displayed in table 24.5.

There are few endemic tree and shrub species in the Sierra Nevada as compared with the Coast Ranges of California. The Sierra Nevada has not been an important center for speciation of woody taxa as compared with other parts of California. Three endemic tree species and twenty-two endemic shrub species occur in the Sierra Nevada. The three endemic trees (Sierra foxtail pine, Piute cypress, and giant sequoia) are found within the southern Sierra, with only giant sequoia occurring in all three geographical subunits of the Sierra Nevada. The twenty-two endemic shrubs are distributed among the following genera: Arctostaphylos (5), Ceanothus (5), Chrysothamnus (2), Ribes (2), Tenestus (2), Berberis (1), Carpenteria (1), Fremontodendron (1), Myrica (1), Pyrrocoma (1), and Salix (1). Several of these shrubs have narrow distribution ranges. Arctostaphylos and Ceanothus, two of the largest genera of shrubs in California, have few endemic representatives in the Sierra Nevada. Both genera are common components of various types of chaparral vegetation, and in the Sierra Nevada they also occur in montane environments as either a seral stage of a coniferous forest series or as a component of a montane chaparral series.

The diversity of habitat types that occur in the Sierra Nevada also explains the great richness of endemic and rare species within this mountain range. The broad plant communities used by Munz and Keck 1959, along with those used in Skinner and Pavlik 1994, provide the basis for recording habitat preferences for rare and/or endemic taxa in this study. Several additional habitat types not based on vegetation were recorded, because many rare taxa seem to be more dependent on them than on the surrounding vegetation type. For example, seventy taxa, or nearly 12% of rare and/or endemic taxa, can be found on rock outcrops. Many endemics and/or rare taxa are located exclusively on a particular rock type, such as carbonate, serpentinite, basalt, or granite. Other taxa have distributions that correspond more closely with elevation zones or that span several habitat types.

Distribution patterns for rare and/or endemic species differ considerably from river basin to river basin, and the distribution of these elements between habitat types is also varied. There are five dominant habitat types: Jeffrey and ponderosa pine forest types contain 211 taxa, the largest concentration of rare and endemic elements in the Sierra; the second largest, the foothill woodland, contains 139 taxa; subalpine forests contain 124 taxa; meadows have 116 taxa; chaparral, 90 taxa.

Of the five habitat types that contain the most rare and endemic taxa, the foothill woodland and chaparral are receiving the greatest increase in impacts and/or fragmentation by urbanization along the western slope of the Sierra Nevada. In chaparral vegetation types, the frequency of fire has been altered to protect other resource values, such as timber and homes. An example of this change in the Sierra Nevada is occurring at the residential development areas of Cameron Park, Pine Hill, and Salmon Falls in El Dorado County. Several rare taxa are restricted or locally endemic to gabbro soils in this area and are impacted by a direct loss of habitat by development. Those taxa that are dependent on fire as part of their life history and ecology may be negatively impacted by long-term changes in the management of chaparral vegetation. The changes may include a shift from fall to spring burning, mechanical treatments, or alteration of the fire frequency

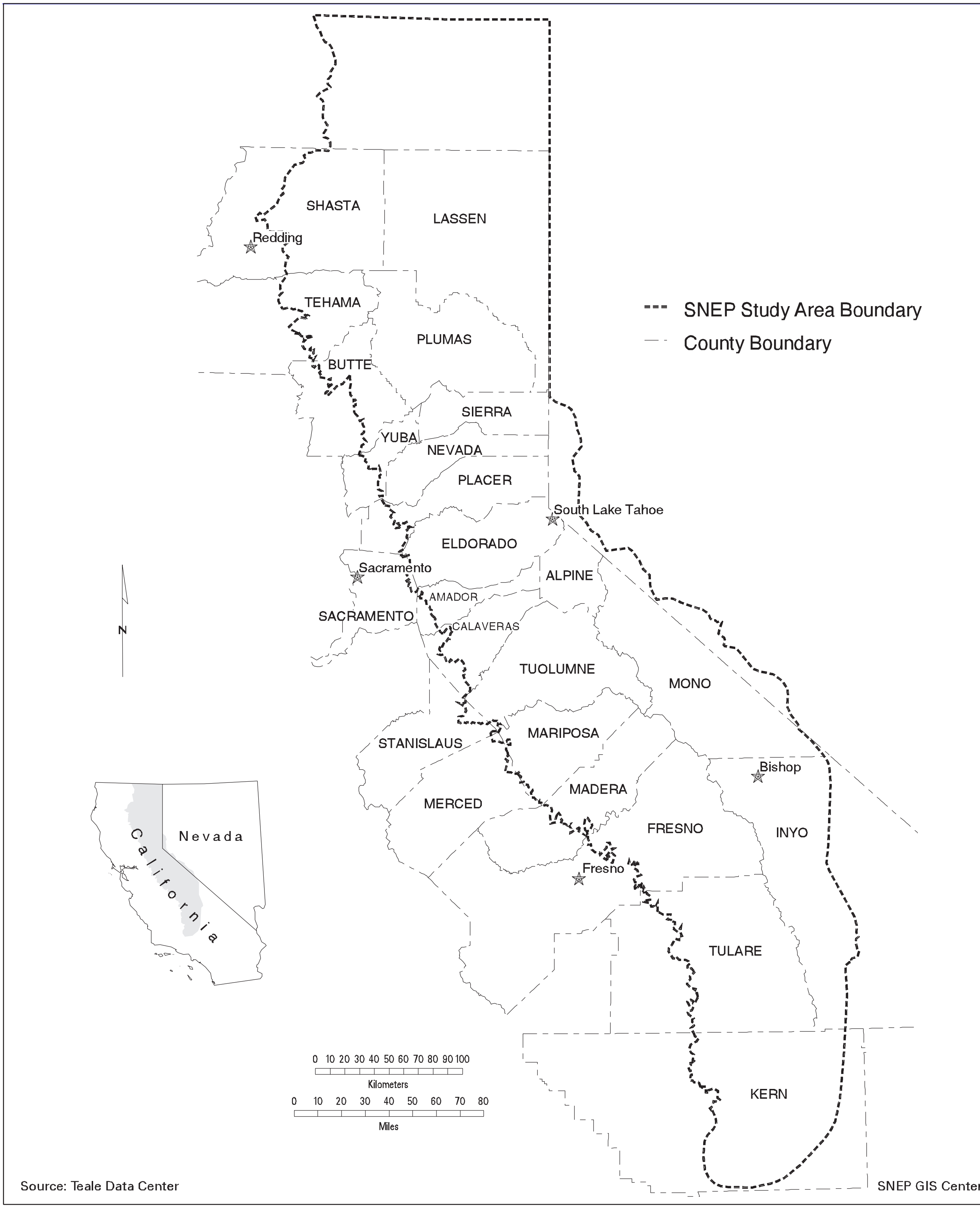

FIGURE 24.2

SNEP study area with county boundaries.

TABLE 24.4

Sierra Nevada endemics at the county level.

County	Endemic Species
Alpine	*Eriogonum microthecum* var. *alpinum* *Galium hypotrichium* ssp. *ebbettsense*
Amador	*Eriogonum apricum* var. *apricum* *Eriogonum apricum* var. *prostratum*
Butte	*Calycadenia oppositifolia* *Calystegia atriplicifolia* ssp. *buttensis* *Clarkia gracilis* ssp. *albicaulis* *Clarkia mosquinii* ssp. *mosquinii* *Clarkia mosquinii* ssp. *xerophylla* *Sidalcea robusta*
Calaveras	*Mimulus whipplei*
El Dorado	*Ceanothus roderickii* *Draba asterophora* var. *macrocarpa* *Galium californicum* ssp. *sierrae* *Navarretia prolifera* ssp. *lutea* *Wyethia reticulata*
Fresno	*Arabis* sp. nov. *Carpenteria californica* *Cordylanthus tenuis* ssp. *barbatus* *Eriogonum nudum* var. *regirivum* *Gilia* sp. nov. *Heterotheca* sp. nov. *Streptanthus fenestratus*
Inyo	*Astragalus sepultipes* *Galium hypotrichium* ssp. *inyoense* *Lomatium rigidum* *Lupinus magnificus* var. *hesperius* *Lupinus pratensis* var. *eriostachys* *Sidalcea covillei*
Kern	*Allium shevockii* *Astragalus ertterae* *Camissonia integrifolia* *Chamaesyce vallis-mortae* *Clarkia tembloriensis* ssp. *calientensis* *Clarkia xantiana* ssp. *parviflora* *Delphinium hanseni* ssp. *kernense* *Eriogonum breedlovei* var. *breedlovei* *Eriogonum kenedyi* var. *pinicola* *Eschscholzia procera* *Galium angustifolium* ssp. *onycense* *Hemizonia arida* *Heterotheca shevockii* *Lomatium shevockii* *Mimulus microphyllus* *Mimulus shevockii* *Streptanthus cordatus* var. *piutensis*
Madera	*Erythronium pluriflorum*
Mariposa	*Clarkia biloba* ssp. *australis* *Clarkia lingulata* *Erigeron mariposanus* *Eriophyllum congdonii* *Lupinus citrinus* var. *deflexus* *Plagiobothrys torreyi* var. *torreyi*
Mono	*Astragalus monoensis* *Carex tiogana* *Draba incrassata* *Lupinus duranii* *Sedum pinetorum* *Senecio pattersonensis*
Nevada	*Berberis sonnei* *Elatine gracilis* *Plagiobothrys glyptocarpus* var. *modestus* *Sidalcea stipularis*
Plumas	*Astragalus lentiformis* *Astragalus webberi* *Calamagrostis* sp. nov. *Ceanothus* sp. nov. *Erigeron lassenianus* var. *deficiens* *Monardella stebbinsii*
Sierra	*Ivesia aperta* var. *canina*
Tulare	*Abronia alpina* *Astragalus shevockii* *Brodiaea insignis* *Castillega praeterita* *Ceanothus pinetorum* *Clarkia springvillensis* *Crythantha incana* *Dudleya cymosa* ssp. *costifolia* *Erigeron multiceps* *Eriogonum nudum* var. *murinum* *Eriogonum twisselmannii* *Erythronium pusaterii* *Geranium coccinnum* *Horkelia tularensis* *Iris munzii* *Lotus oblongifolius* ssp. *cupreus* *Mimulus norrisii* *Oreonana purpurascens* *Phacelia eisenii* var. *brandegana* *Ribes tularense* *Silene aperta*
Tuolumne	*Allium tribracteatum* *Allium tuolumnense* *Brodiaea pallida* *Erythronium tuolumnense* *Iris hartwegii* ssp. *columbiana* *Senecio clevelandii* var. *heterophyllus* *Verbena californica*

or intensity of burns. Blue oak savannas (part of the foothill woodland) are also being impacted by land-use changes. Located along the western edge of the Sierra Nevada, blue oak savannas have a long historic use primarily for cattle grazing. What was once extensive open rangeland is now increasingly being subdivided into "ranchettes" and other semirural residential communities within commute distance of the growing urban centers scattered throughout the Central Valley. Another change impacting rare and endemic taxa is the increased infestation of invasive exotic and weedy plants such as yellow star-thistle (Centaurea solstitalis) and Scotch broom (Cytisus scoparius).

Because of their economic value, many hectares of Jeffrey and ponderosa pine forests have been systematically logged for over a century. Few meadow environments have not been intensively grazed in the past century, and grazing is identified as a potential threat to many of the rare taxa restricted to meadow and riparian environments. The subalpine and alpine areas with endemic and rare plants are generally believed to be in stable condition mainly because difficult access traditionally limited land uses. However, rare plants have also been negatively impacted by some recreational uses even in wilderness areas. In general, land uses with the greatest impacts have been at the low and middle elevations of the Sierra Nevada. Human activities, whether grazing, logging, mining, or recreation, by and of themselves may not threaten species. Rather, it is the interactions between the timing, intensity, frequency, and distribution of these various activities

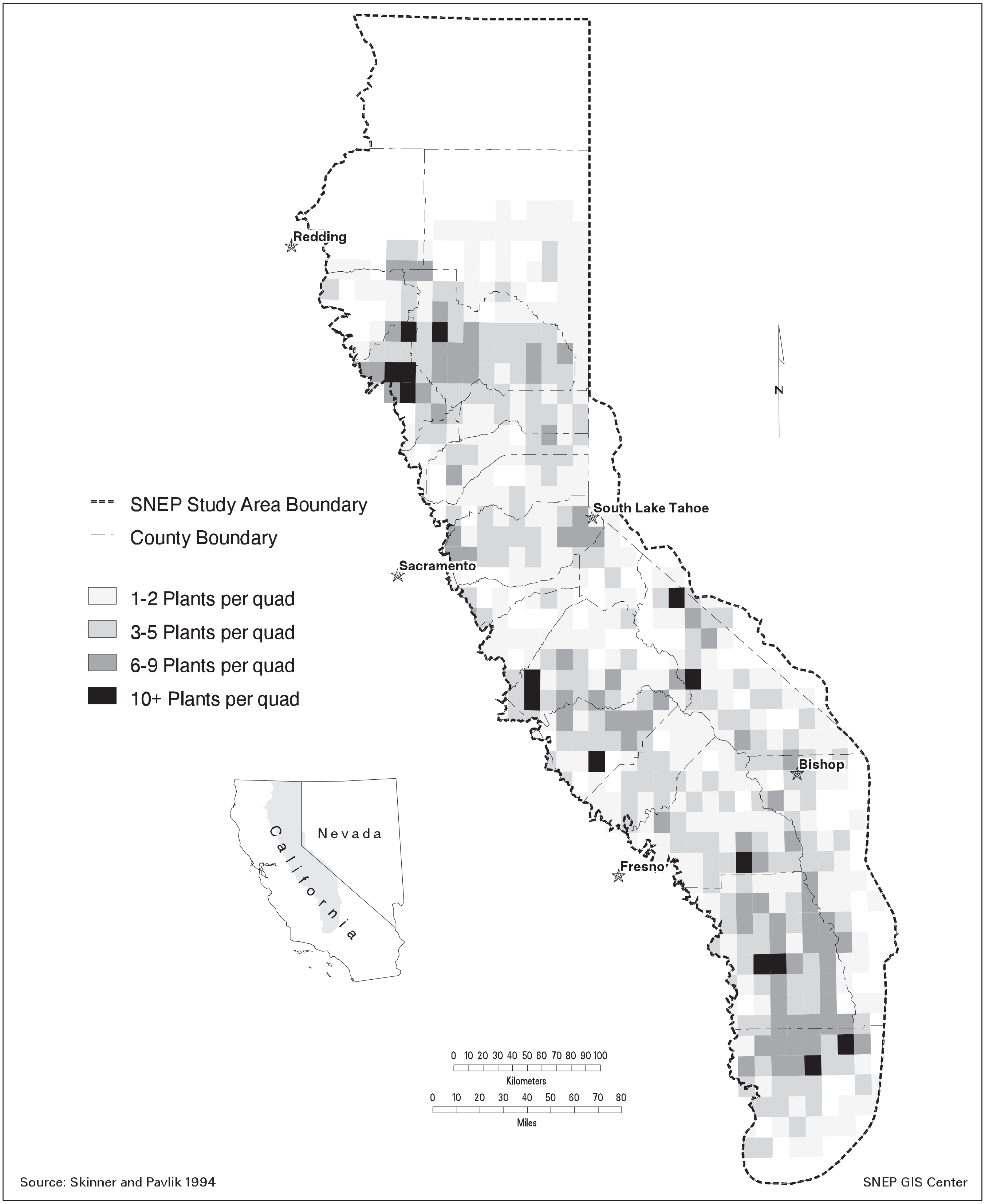

FIGURE 24.3

Distribution of rare plants by topographic quadrangle (Skinner and Pavlik 1994).

TABLE 24.5

Distribution of Sierran rare and endemic plants by largest genera.

Genera	Number of Taxa from Database	Sierran Endemics	Rare Taxa	Rare and Endemic
Eriogonum	27	23	18	14
Astragalus	22	14	16	8
Mimulus	19	16	15	11
Clarkia	18	18	13	13
Lupinus	17	17	9	9
Phacelia	15	13	9	7
Erigeron	14	13	9	8
Carex	14	5	13	4
Ivesia	12	10	8	6
Allium	11	9	8	5
Streptanthus	10	7	7	4
Totals	179	145	125	89

and practices that can have significant adverse effects on long-term conservation objectives for rare species.

Conservation guidelines, strategies, or plans for endemic and rare taxa in the Sierra Nevada need to take into account land-use changes that are occurring or are projected to occur in the near future. The majority of the Sierra Nevada is federal land administered chiefly by the Bureau of Land Management, the Forest Service, and the National Park Service. To meet the intent of several federal laws and regulations, these agencies have developed policies to conserve species and to reduce the likelihood that species will become threatened or endangered under federal law. However, not all Sierran endemics and rare plants occur on public land. Many are located on land zoned for a variety of land uses, where management practices and policies range from major alteration or conversion of the landscape by agriculture or residential uses to utilization of natural resources to protection for watershed and other amenity values (Messick 1995). Besides zoning and land uses, individual plant occurrences are at considerable risk if the ecology of the species along with its distribution pattern is not part of the land management decision-making process (Lesica and Allendorf 1992, 1995; Schemske et al. 1994).

Adverse impacts to many rare and endemic plants could be lessened by an improved analysis within the required environmental public review statutes. The National Environmental Policy Act (NEPA) for federal actions and the California Environmental Quality Act (CEQA) for nonfederal actions have to date addressed rare plant issues inconsistently. As a minimum, NEPA and CEQA documents need to clearly state the analysis used to assess the distribution and population dynamics of rare plant taxa and discuss potential threats, the ecology of the species, and management recommendations considered as either conservation measures or mitigation actions to reduce adverse impacts. These NEPA and CEQA documents also need to be viewed in a larger context to evaluate the cumulative impacts as well as monitor the effectiveness of conservation and species protection actions.

CONCLUSION

We can only estimate that over half of the California vascular flora occurs within the boundary of the Sierra Nevada because no detailed floristic treatment exists. The situation for nonvascular plants is even more problematic. Several smaller-scale floristic studies have contributed to our understanding of gross distribution patterns in recent years: localized floras such as those undertaken for master's theses, the recent flora of Butte County, or the revised flora of Lassen Volcanic National Park. However, much work remains to be done (Wilken 1995). Even for nonrare Sierran endemics, distribution data are incomplete, and this study does not resolve many of the distribution questions. Our collective understanding of which species are endemic or rare to the Sierra Nevada will be modified as fieldwork continues in more remote areas and focused surveys are conducted for individual species. All checklists and floras need to document voucher specimens as the basis for the catalogue of names presented so that future researchers can determine the accuracy of identification and need to provide a sense of the depth of study upon which the flora or checklist is based. This need is critical because monographic studies may change the taxonomic circumscription of certain plant groups or clarify species that traditionally have been difficult to identify in the field.

The Sierra Nevada remains one of the botanical gems of North America. New plant species are still being discovered in this range, and land managers across this magnificent landscape need to be aware of the unique biodiversity contained within the Sierra Nevada. Land managers should appreciate the evolutionary forces that have contributed to such a remarkable rare and endemic flora and provide appropriate levels of conservation to ensure that this resource is sustained for the American people.

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