Biodiversity in the Sierra Nevada[1]

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The earliest explorers of the Sierra Nevada hailed the mountain range for its unsurpassed scenery. Although a significant component of that beauty was an especially rich assemblage of plants and animals, it was not until many decades later that the Sierra Nevada's wealth of biodiversity was appreciated fully and documented in earnest. Indeed, by the time naturalists, including the legendary John Muir, began to write of the range's biological assets, features such as ancient forests, alpine meadows, and stream corridors were under full assault from unsustainable levels of logging, livestock grazing, and mining. Grizzly bears, wolverines, mountain sheep, and condors had disappeared outright or were far along the path toward disappearance in the Sierra Nevada. Unknown populations of more cryptic species were likely extirpated also, reducing the species' genetic diversity and either disrupting or permanently altering ecological interactions. We will never have complete knowledge of species richness, composition, and distribution of the native biodiversity of the Sierra Nevada prior to European-American settlement.

Although the number of species in a given landscape and the distribution of individuals among species are the most commonly implied meanings of the term "biodiversity," biodiversity encompasses the full range of life, from genes to complex ecological communities, at all spatial, temporal, and organizational levels. Conservation of biodiversity cannot be achieved without also conserving the ecological and evolutionary processes that sustain life. Those processes, in turn, may be affected by changes in the identity, abundance, and geographic distribution of species. Most theoretical and empirical work on biodiversity has tended to focus on species, assemblages, and communities. These units are among the most intuitive and easily delineated forms of biodiversity, and intentional or inadvertent alterations to their dynamics, structure, and composition are relatively amenable to detection and management.

As the contributions in this section emphasize, conservation and management of the biodiversity of the Sierra Nevada not only is a priority on its own merits, but also is affected by and tightly linked to our ability to achieve other environmental goals. For example, invasion of non-native species of plants—at rates that may be exacerbated by climate change—can affect fire regimes and, by extension, forest health. Because water is a limiting resource for a majority of native species as well as for humans, water allocation strategies for human uses have direct and indirect effects on patterns of biodiversity. In some cases, individual species play key roles in sustaining ecological processes and community structure. These taxa include species that contribute disproportionately to the transfer of matter and energy (sometimes called keystone species), structure the environment and create opportunities for additional species (ecological engineers), or exercise control over competitive dominants, thereby promoting increased biotic diversity (strong interactors).

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[1] This paper provides an introduction to the biodiversity session presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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Few geographic regions illustrate the full suite of economic and aesthetic values attributed to biodiversity as well as the Sierra Nevada. Not coincidentally, few regions can boast a similar range of underlying topographic and climatic gradients, creating a variety of local environments that collectively support a substantial array of life forms, land cover types, and associated animal and plant species. Species richness and endemism of temperate conifer forests in the Sierra Nevada is among the greatest in the world, and the effect of giant sequoia on forest structure has been recognized as a globally outstanding rare phenomenon (Ricketts and others 1999). Using a rarity-weighted index, The Nature Conservancy ranked the species richness of the Sierra Nevada among the top 11 regions in the United States (Stein and others 2000). The World Wildlife Fund considers the Sierra Nevada to be among the 32 most biologically distinct of the 116 ecoregions in the United States and Canada (Ricketts and others 1999). High endemism has been documented among mammals (especially rodents), butterflies, and vascular plants. Lesser-known taxonomic groups, including non-vascular plants and many groups of invertebrates, are likely to be equally distinct.

The cumulative effects of a century and a half of human activity now threaten the viability of a number of species that primarily occur within the Sierra Nevada Bioregion. At lower elevations, extraction of timber and fire suppression have simplified the structure of ponderosa pine and mixed conifer forests, increased the probability of major fire events, and facilitated outbreaks of herbivorous insects and pathogens. Introduced fishes are a major contributor to declines in populations of amphibians (and an unknown diversity of aquatic invertebrates), whereas resources for native fishes are degraded by dams, livestock grazing, and logging. More recently, deposition of ozone and other airborne pollutants at intermediate elevations has begun to have demonstrable effects on some species of trees and lichens (Ricketts and others 1999).

Although the conservation outlook for the Sierra Nevada is by certain measures cause for concern, vulnerability assessments presented in the recent Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement (Volume 4, Appendix R) offer some grounds for optimism. The spatial extent of area occupied by more than half of the region's species of birds, for example, is either stable or increasing. Of 23 identified threats to species persistence, those that affected the greatest proportion of plant species assessed—such as roads (0.65), mechanical treatments (0.61), and off-highway vehicles (0.56)—result from patterns of human land use that can be modified or changed, as opposed to now-altered ecological processes that may be difficult to reconstruct.

The vulnerability assessments in the Forest Plan demonstrate that conservation priorities and strategies are likely to vary among versus within taxonomic groups. For example, amphibians accounted for only 27 of the 427 species of terrestrial vertebrates evaluated (6 percent) *(fig. 1)*. However, nine of those species—a higher proportion than in any other taxonomic group—are judged to have relatively high risk of losing viability due to combinations of natural phenomena and human land uses *(fig. 2)*. Of the 37 taxa of fishes native to the Sierra Nevada, 19 are considered to be highly vulnerable and 12 are moderately vulnerable (Forest Service 2001). Clearly certain taxonomic groups are disproportionately vulnerable and managers need to better understand why that is so and be prepared to respond accordingly. In addition, there are several noticeable differences among taxonomic groups with respect to the three variables used to score overall vulnerability (population size, population trend, and change in distribution). Mammals have the greatest proportion of species with population sizes larger than 10,000 (0.60, *table 1*), but the smallest proportion of species with stable or increasing geographic ranges (0.19, *table 2*).

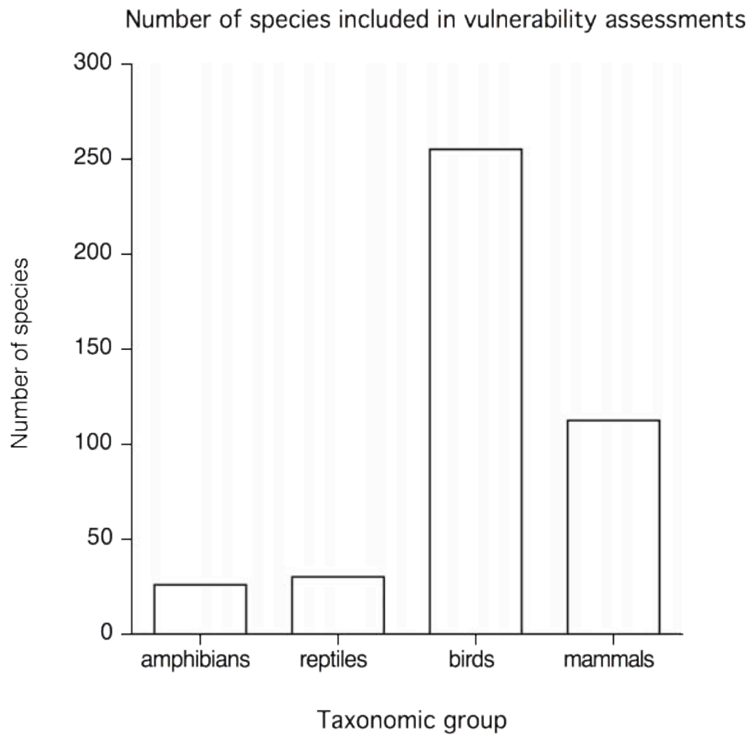

Figure 1— Numbers of species included in vulnerability assessments in the Sierra Nevada Forest Plan Amendment Environmental Impact Statement (2001) Appendix R.

Table 1— *Population size (number of individuals) of terrestrial vertebrates in the Sierra Nevada.*

	Proportion of species				
Population size (number of individuals)	**all taxa**	**amphibians**	**reptiles**	**birds**	**mammals**
may be extirpated	0.02	0.07	0.00	0.02	0.04
1 - 100	0.06	0.07	0.00	0.09	0.00
101 – 1,000	0.27	0.38	0.16	0.34	0.12
1,001 – 10,000	0.15	0.22	0.10	0.11	0.25
greater than 10,000	0.50	0.26	0.74	0.44	0.59
	1.00	1.00	1.00	1.00	1.00

Table 2— *Decline in area occupied by terrestrial vertebrates in the Sierra Nevada.*

	Proportion of species				
Percent decline in area occupied	**all taxa**	**amphibians**	**reptiles**	**birds**	**mammals**
90 – 100 percent	0.04	0.15	0.00	0.02	0.05
50 – 89 percent	0.07	0.19	0.10	0.05	0.08
Less than 50 percent	0.44	0.37	0.45	0.35	0.68
Stable or increasing	0.45	0.30	0.45	0.58	0.19
	1.00	1.00	1.00	1.00	1.00

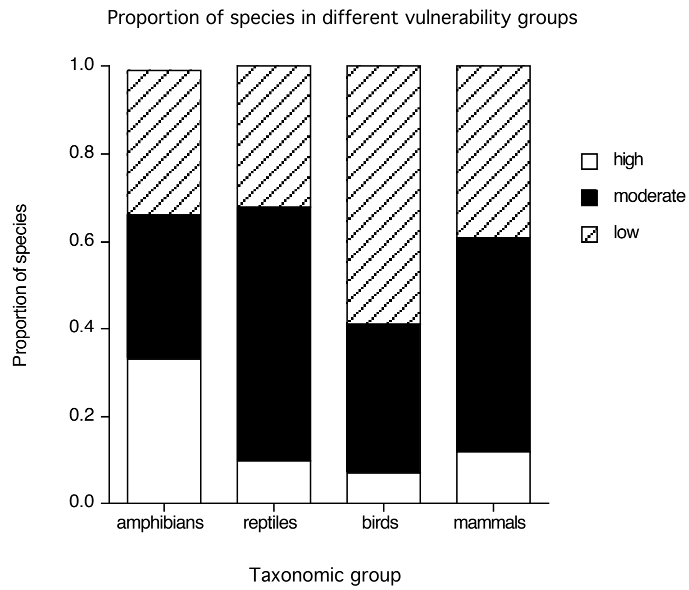

Figure 2— Proportions of species in different vulnerability groups, from the Sierra Nevada Forest Plan Amendment Environmental Impact Statement (2001) Appendix R.

In addition to evaluating the status of native terrestrial vertebrates in the Sierra Nevada Bioregion, vulnerability assessments have addressed dependence of individual species on four high-priority land cover types: late seral and old growth forest, west-side foothill oak woodland, riparian and meadow, and aquatic. Aquatic ecosystems have the highest proportion of dependent (highly resource-specific) species (0.79), whereas late seral and old growth forest had the lowest proportion of dependent species (0.69) *(fig. 3)*. Patterns of dependence, however, vary among taxonomic groups; for instance, a much higher proportion of amphibians (0.78) than birds or mammals (both 0.19) facultatively use late seral and old growth vegetation. By contrast, because amphibians inhabit uplands for much of their adult life stage, the proportion of species dependent on aquatic systems is higher among birds (0.73) and mammals (0.96) than among amphibians (0.41).

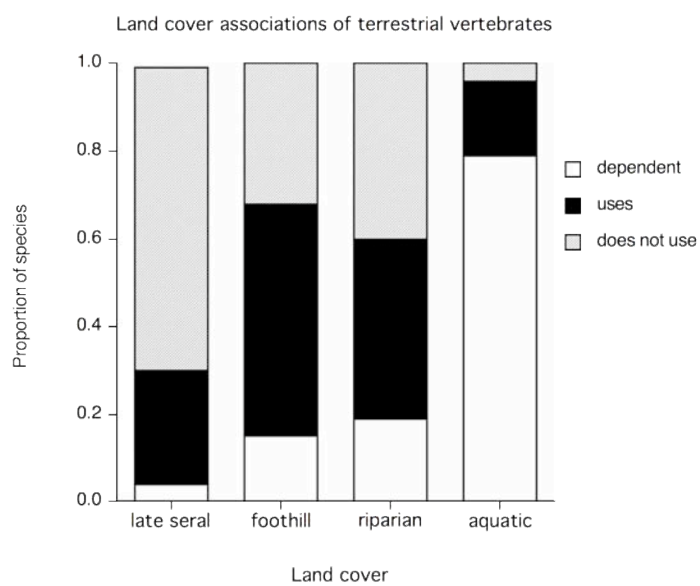

Figure 3— Land cover associations of terrestrial vertebrates.

Comparison of vulnerability assessments for terrestrial vertebrates and aquatic vertebrates (fishes) again highlights both similarities and differences. The proportion of species with downward population trends is nearly equal among terrestrial vertebrates and fishes (0.48 and 0.46 respectively, *fig. 4*), but declines in area occupied are more pronounced among fishes than among terrestrial vertebrates (*fig. 5)*. This suggests a general pattern of higher vulnerability among aquatic species. Aquatic habitats of the Sierra Nevada are probably those most sensitive to anthropogenic disturbances. Wet meadows, streams, riparian corridors, ponds, and lakes have experienced varying, but elevated, levels of degradation in recent decades; Correspondingly, it should not be a surprise that aquatic biodiversity appears to be most vulnerable.

Floral diversity in the Sierra Nevada is especially notable. Some 3,000 species of vascular plants alone are associated with vegetation communities including, but by no means limited to, chaparral, foothill, and pinyon-juniper woodlands; forests of ponderosa pine, mixed conifers, white fir, red fir, and lodgepole pine; alpine meadows; and sagebrush scrub. Yet of the 135 species evaluated in the Sierra Nevada Forest Plan Amendment Environmental Impact Statement (Forest Service 2001)—species either listed as endangered or threatened, proposed for federal listing, or considered sensitive by the Forest Service—only 26 (19 percent, comprising less than 1 percent of the total number of vascular plants) are considered to be at high risk of losing viability. A full third of plant species are judged to have low risk of viability loss. Perennials (mainly herbs) accounted for the majority of species in the high and moderate vulnerability groups (81 and 63 percent, respectively). As noted above, human land uses, ranging from urbanization and development of ski areas to livestock grazing and mining, are currently the most pervasive threats to plants in the Sierra Nevada. Over the next several decades, the importance of managing more diffuse and insidious threats, such as noxious weeds and altered hydrologic regimes (both of which affect about 30 percent of the plant species evaluated), is likely to increase.

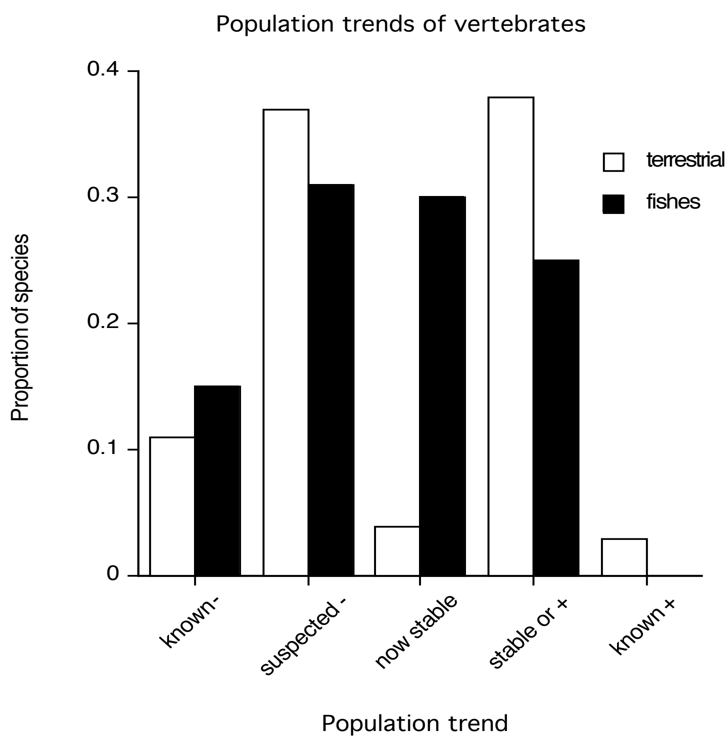

Figure 4— Population trends of vertebrates.

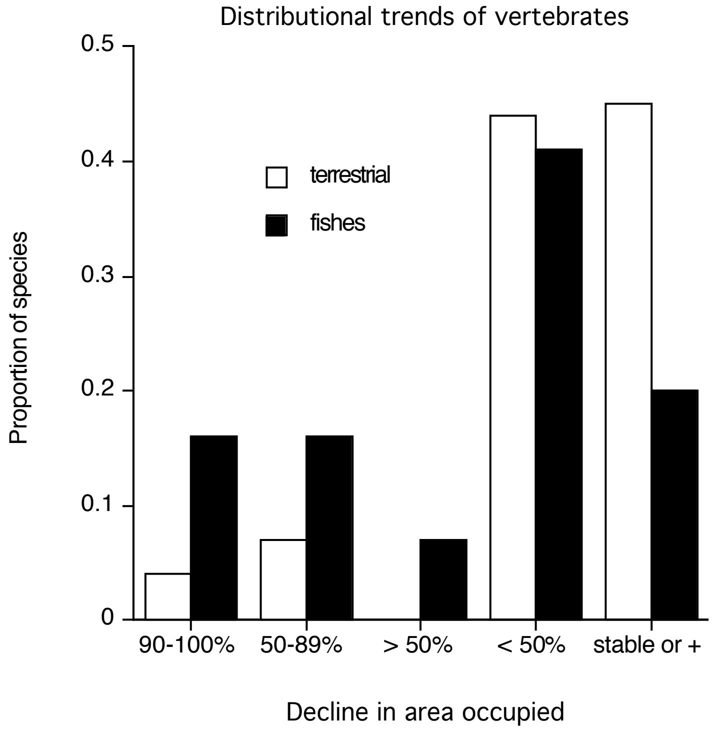

Figure 5— Distributional trends of vertebrates.

Perhaps most heartening is that these frank and reliable assessments of the Sierra Nevada's biodiversity have been developed by the dominant land management agency itself. The summary statistics compiled by the Forest Service are mirrored by other treatments. Dobson and others (1997) used data on the distributions of federally listed threatened and endangered species to identify "hotspots" of imperiled biodiversity from a nationwide database of occurrence by county. Although several Sierra Nevada counties are included among those with the highest numbers of listed plants, those same counties are conspicuously absent from the lists of counties with the highest numbers of listed mammals, birds, fishes, and select invertebrates. Although portions of coastal southern and central California, the Mojave Desert, and Owens Valley are considered to be national hot spots of species at risk, the Sierra Nevada is not. A less systematic assessment can be drawn from "Life on the Edge," a portrait of 100 species of listed and at-risk animals from across California. Just three of the 17 mammals presented have portions of their ranges in the Sierra Nevada. Similarly, only five of 29 birds, three of 19 fishes, one of 17 reptiles, and none of the 18 species of invertebrates considered to be imperiled in California occur in the Sierra Nevada. Accordingly, despite relatively high levels of endemism, a substantial number of ecological associations with narrow distributions, and a long history of intensive human land use, the Sierra Nevada retains most of its most irreplaceable elements.

Presentations from the Sierra Nevada Science Symposium cannot possibly embrace the breadth and depth of biodiversity issues, the challenges faced by land managers, and associated scientific efforts. For example, this symposium could have addressed the current hot list of species that are under active review for listing under the Federal and State endangered species acts, such as California spotted owls, willow flycatchers, mountain yellow-legged frogs, among others. However, we believed that it would be more informative in this forum to examine the more generic forms of current and future threats to biodiversity within the bioregion. The authors in this section discuss four key issue areas in which science is helping to guide management of biodiversity in the Sierra Nevada mountain range. Pat Manley describes her assessment of biodiversity in the Lake Tahoe basin, in which intensive deforestation dramatically altered composition and structure of forest stands and intensive grazing had substantial impacts on riparian communities and upland meadows. Although these environmental ravages ceased many years ago, even more-pervasive impacts are now manifest as the basin is subject to the highest rates of human visitation and recreation in the Sierra Nevada. Manley fairly argues that if conservation efforts to maintain Tahoe's biotic diversity succeed, then the likelihood that those resources can be sustained elsewhere in the range is considerable. Bill Zielinski considers the fate of one particularly critical group of species in the Sierra Nevada. He argues that mesocarnivores, including wolverines, fishers, martens, and Sierra Nevada red foxes, are especially important to ecosystem function because of their diversity of ecological roles. Zielinski also documents significant declines of several species and makes recommendations for recovery efforts and future management. Carla D'Antonio and colleagues grapple with the most far-reaching and insidious threat to native biotic diversity in the Sierra Nevada: invasive non-native species. They document the scope of the challenge posed by plant invasions in locations ranging from foothill grasslands, in which assemblages of native plants have been nearly completely replaced by non-native species, to high-elevation communities that remain nearly free of non-natives. Frank Davis and colleagues highlight the need for a framework to deliver the information necessary to evaluate conservation opportunities and help planners and managers develop effective long-term and comprehensive conservation and land-protection strategies for the Sierra Nevada. They discuss how site prioritization can be carried out using available data on the distribution of biotic resources, threats to those resources, and costs of conservation optimized over a large landscape.

The fate of the biodiversity of the Sierra Nevada in a state that will have fifty million human residents in the near future is uncertain. But it appears that significant opportunities are available to land managers to retain and sustain the Sierra Nevada's biological diversity. Relatively few portions of this region have undergone the irreversible habitat conversions witnessed in many other parts of California. Despite unsustainable logging, heavy livestock grazing, even hydraulic mining, planners are nonetheless still left with a landscape capable of restoration, and a species assemblage that is largely still intact. The ill effects of large scale urbanization and invasive species are only just beginning to make their mark in this ecoregion. Immediate attention needs to be pointed to the foothills where significant urbanization has occurred at locations along transportation corridors, and will become more serious in the coming decades.

Suffice it to say that the need for effective management of the Sierra Nevada's resources, and the need for good science to inform that management, will only increase. Lessons can be drawn from previous successful programs, from the systematic approaches that have been taken to understand the structure and dynamics of sequoia forests to viability analyses of declining populations of California spotted owls. The history of scientific review, synthesis, and assessment documented in the Sierra Nevada Ecosystem Project volumes (SNEP 1996), as well as in the recent Sierra Nevada Forest Plan Amendment, also will serve as essential resources for future generations of decision-makers and land managers.

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