

## Extreme Variability in Tree-Ring Chronologies from Different Physical Settings<sup>1</sup>

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Long chronologies of annually resolved past-climate proxies derived from tree rings are key to assessing the role of temperature and precipitation variability and trends on subalpine forests. Especially important contributors to the time-series data are tree-ring records from high-elevation, long-lived conifers in western North America. Although high-elevation trees are generally considered good recorders of past climate, little research has investigated the influence of kilometer-scale physical setting on the sensitivity of tree-ring chronologies. Using proxies for soil moisture and radiation derived from a digital elevation model, increment cores were systematically collected for 12 tree-ring chronologies in extreme biophysical settings from three sites in the Sierra Nevada Mountains of California. A multivariate analysis of the chronologies is presented, which illustrates the importance of considering the physical template, especially as it relates to soil moisture, as a patterning agent of this key paleoclimatic resource. Preliminary results indicate that soil moisture affects chronology sensitivity, pointing to the need to account for physical setting when sampling.

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## The Sierra Nevada Global Change Research Program<sup>1</sup>

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The Sierra Nevada Global Change Research Program began in 1991 as a component of the National Park Service's (now U.S. Geological Survey's) Global Change Research Program. The program's core study areas are Sequoia, Kings Canyon, and Yosemite National Parks. The goal is to understand and predict the effects of environmental changes on montane forests. To reach this end, the program consists of integrated studies organized around three themes: paleoecology, contemporary ecology, and modeling. The paleoecological theme takes advantage of the Sierra Nevada's rich endowment of tree-ring and palynological resources to develop an understanding of past climatic changes and the consequent responses of fire regimes and forests. The contemporary ecology theme takes advantage of the Sierra Nevada's substantive climatic gradients as "natural experiments," allowing researchers to evaluate climatic mechanisms controlling forest structure, composition, and dynamics. The modeling theme integrates findings from paleoecological and contemporary studies; it is a vehicle for scaling up the program's mechanistic findings to regional landscapes and predicting which parts of montane landscapes may be most sensitive to future environmental changes. To date, the program has produced several results both of broad interest to biologists and useful to land managers.

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## Climate Change and the Bay-Delta Watershed<sup>1</sup>

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California's primary hydrologic system, the San Francisco estuary and its upstream watershed, is vulnerable to the regional hydrologic consequences of projected global climate change. Projected temperature anomalies from a global climate model are used to drive a combined model of watershed hydrology and estuarine dynamics. This poster presents computer animations representing these projections at several spatial scales over the coming century. By 2090, a projected temperature increase of 2.1 degrees Celsius results in a loss of about half of the average April snowpack storage, with greatest losses in the northern headwaters. Consequently, spring runoff is reduced by 5.6 km<sup>3</sup>, with associated increases in winter flood peaks. The smaller spring flows yield spring and summer salinity increases of up to 9 psu in the delta, with larger increases in wet years. This poster uses animations to provide a powerful means of communicating the broad scope of these hydrologic and estuarine impacts of climate change in California.

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## Climate Change as an Ecosystem Architect: Examples from High-Elevation Pine Forests<sup>1</sup>

Constance Millar,<sup>2</sup> Diane Delany,<sup>2</sup> Robert Westfall,<sup>2</sup> and John King<sup>3</sup>

Advances in ecology and conservation during the 20th century motivated a shift from viewing nature as static and typological to dynamic and processual. Static concepts, however, still constrain our understanding of natural dynamism and limit our conservation successes. Recent advances in earth system sciences, which characterize recurrent climate change as a central physical force on earth, have not been well incorporated into evolutionary and ecological theory nor yet translated into regional conservation and management practice.

Preliminary results from several studies of pine ecosystems in the high Sierra Nevada and adjacent Great Basin ranges provide examples of forest response to historic climate change. In all studies, standard tree-ring and ecological plot analysis methods were used. Correlated growth response and meadow/snowfield invasions of whitebark pine and lodgepole pine during four multidecadal climate periods in the 20th century are documented as well as decadal cycles in limber pine growth related to dry and wet periods over the past two centuries. Century-scale growth variability of limber pine forests over the past 4,000 years correlates with major temperature and precipitation cycles as derived from independent climate indicators. Major demographic shifts of limber pine include cyclic extirpation and recolonization events that appear correlated to multidecadal climate phases. Such natural variability has not been figured into conservation baselines and planning.

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## Sagebrush Expansion in Meadows of the Kern Plateau, Southern Sierra Nevada<sup>1</sup>

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Over the last century, significant vegetation change and stream incision have occurred in meadows of the Kern Plateau in the southern Sierra Nevada. Rothrock's sagebrush, *Artemisia rothrockii*, has expanded extensively into areas of wet meadow vegetation. Lowered water tables as a result of stream incision contribute to shrub expansion; however, sagebrush also invades unincised areas. This research project examines rates and spatial patterns of sagebrush expansion and factors correlated with local changes in sagebrush distribution.

Using Geographic Information Systems, repeat aerial photographs were rectified to identify changes in sagebrush distributions. The initial comparison of time points shows many new areas of sagebrush as well as isolated local recovery of wet meadow vegetation.

To characterize areas of sagebrush expansion, environmental and landscape variables were measured in sites with and without recent expansion. Preliminary results show that areas of new sagebrush are intermediate in soil moisture, relative elevation, and sagebrush density between intact herbaceous vegetation and older sagebrush. They occur on all geomorphic surfaces including floodplains, newly incised terraces, and older terraces. The authors are now using classification trees to identify combinations of variables that best predict conditions for sagebrush expansion. These classification trees can provide a management tool to reduce further sagebrush expansion.

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## Thermodynamics of Snowpack at Gin Flat, Yosemite National Park, during Winter and Spring 2002<sup>1</sup>

Michael D. Dettinger<sup>2</sup> and Frank Gehrke<sup>3</sup>

The Gin Flat automated snow-telemetry site, at 7,050 feet in elevation in Yosemite National Park, has been augmented during the past 2 years to measure components of the water and radiation budgets of the snowpack, in addition to the precipitation, temperatures, and snow-water content measurements typical of such sites. New measurements at Gin Flat include snow thickness, incoming solar radiation, and net radiation to the snow surface. Together, these measurements characterize gross water and radiative heat budgets of the winter snowpack, as well as snow density. During 2002, temperatures within the (6-foot) snowpack were monitored at 1-foot vertical intervals as indicators of the time- and depth-varying thermodynamics of the snowpack. The measurements at Gin Flat, taken together, illustrate multiday downwelling of cold into the Sierra Nevada snowpack during two prolonged cold snaps; however, for the most part, the snowpack remained essentially at 0 °C throughout the winter and spring. Additional instrumentation, such as that operated at Gin Flat, is proving to be robust to the elements and provides new insights into the workings of Sierra Nevada snowpacks. Augmentations have now been included at several more sites, including Tuolumne Meadows and Dana Flat in Yosemite National Park.

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## **Snow, Topography, and the Diurnal Cycle in Streamflow<sup>1</sup>**

**Jessica Lundquist,<sup>2</sup> Michael Dettinger,<sup>3</sup> Daniel Cayan,<sup>2</sup> and Noah Knowles<sup>2</sup>**

Hourly measurements of river discharge provide a widely available, but as yet underutilized, source of information about snowmelt processes, providing direct information on basin output at a fine temporal scale. The timing of streamflow variation within each day reflects the daily timing of snowmelt maxima and minima, modulated by travel times through the snowpack, hillslopes, and stream channels to the gauging stations where they are measured. The daily timing of the diurnal cycle consequently reflects the seasonal evolution of travel times and, by extension, the evolution of snowpack and snow cover conditions within contributing watersheds.

Traditional theories, based on numerical models and localized, small-basin observations, report that the hour of day of maximum flow becomes earlier as the snowpack thins, reflecting shorter travel times for surface melt to reach the base of the snowpack. However, an examination of hourly discharge from 100 basins in the western United States, ranging in size from 1 square kilometer to 10,812 square kilometers, reveals a more complex situation. Depending on basin size and topography, diurnal timing often depends strongly on the discharge magnitude and on the snowmelt location.

In most of the basins examined, at the end of the melt season, the hour of maximum discharge shifts to later in the day, reflecting increased travel times as the snowline retreats to higher elevations. The rate of this retreat is more rapid in dry years than in wet years and may provide a measure of how basin snow cover and soil moisture respond to interannual climate variations.

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## **Historic Variability of Vegetation in Glass Creek Meadow, Inyo National Forest, California, and Its Role in Resource Management Planning<sup>1</sup>**

**Wallace Woolfenden<sup>2</sup>**

The study of past variability of ecosystems is important for understanding ecosystem dynamics that occur at time scales greater than the time scale at which they are usually observed, for evaluating present ecosystem conditions and for planning for their sustainability. The history of Glass Creek Meadow vegetation was interpreted from a 3,000-year pollen sequence extracted from radiocarbon-dated sediment cores in order to examine the value of historic reference conditions in managing this type of ecosystem. In the top section of the sequence, an interval of low pollen concentration above a volcanic ash bed and mixed with volcanic tephra marks the effect of the Glass Creek eruption of about 600 years ago. An increase in willow pollen followed by an increase in aster and saltbush pollen is the major indicator of vegetation change during and after the eruption. A large spike of sedimentary charcoal and a decrease in fir and buttercup pollen between 100 and 225 years ago indicate a fire effect on the meadow and surrounding pine-fir forest. A decrease in willow pollen to low levels by 300 years ago to the present, along with fairly stable proportions of forb, grass, and sedge pollen, contradicts the assessment of the meadow as having been overgrazed.

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## Effects of Altered Summer Precipitation on Sierra Nevada Shrubs<sup>1</sup>

Michael E. Loik<sup>2</sup>

Current global climate models predict a 25 to 50 percent increase in precipitation for California by 2095. The effects of spatial and temporal patterns of precipitation change on plants are uncertain. An increase in summer monsoon activity is considered likely for the eastern Sierra Nevada. Although increased precipitation could be beneficial for plants, not all species can equally utilize summer rain.

The author tested hypotheses regarding increased summer precipitation on photosynthesis for *Artemisia tridentata* and *Purshia tridentata*. Supplemental water was added over the range of 0 to 200 percent of average precipitation, over 1 to 14 days, and at three elevations; water relations, photosynthesis, and stress within PSII were measured. Photosynthesis as a function of added water increased more for *A. tridentata* than for *P. tridentata*. Both species responded maximally at 2 days following addition. Several small additions elicited more of a response than did one large addition. Photosynthesis was greater for plants at higher elevations. Future patterns of photosynthesis in response to increased summer rainfall will be species-specific and will depend on the timing, magnitude, and spatial scale of actual precipitation changes. Results of this study will contribute to the development of restoration plans for recovery of damaged habitats.

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## High Temperature Tolerance for *Purshia tridentata* Exposed to Increased Summer Precipitation Across an Elevation Gradient<sup>1</sup>

Gitane L. Royce<sup>2</sup> and Michael E. Loik<sup>3</sup>

Current global climate models predict increased precipitation for California by the year 2050. This research focused on the impacts of climate change on the arid shrub *Purshia tridentata* (Rosaceae). Three sites spanning a total of 1,400 meters in elevation were chosen. The authors tested the hypotheses that (1) *P. tridentata* at low elevation is better able to survive high temperatures than it is at high elevation and (2) increased precipitation will enhance its tolerance of high temperatures. *In situ* watering manipulations were used to determine the potential impact of increased precipitation on *P. tridentata*. Thermal stress was assessed by measuring damage to cell and chloroplast membranes, as well as the ability to uptake CO<sub>2</sub>. At 45 °C, CO<sub>2</sub> flux was -0.104 mol m<sup>-2</sup> s<sup>-1</sup> for plants at 1,725 meters and -3.056 mol m<sup>-2</sup> s<sup>-1</sup> for plants at 3,070 meters. FV/FM was enhanced by 5.5 percent for 1,725 meters, 10.3 percent for 2,600 meters, and 24.8 percent for 3,070 meters when compared with untreated plants at 45 °C (P < 0.0409). Based on electrolyte leakage, the LT50 was 56 °C at 1,725 meters, 54 °C at 2,600 meters, and 49 °C at 3,070 meters. These results indicate that plants at lower-elevation sites are better able to withstand extreme high temperatures and that enhanced tolerance to high temperatures due to increased precipitation will be most prominent for upper elevations.

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# Climate, Snow, Water, and Chemistry Observations in Yosemite National Park: A Monitoring Network for Environmental Change<sup>1</sup>

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Yosemite National Park sits astride the high Sierra Nevada and encompasses the watersheds of two important rivers, the Merced and Tuolumne. Its pristine conditions, together with the access that park roads and trails provide to the high country, make it a unique setting for scientific studies of the Sierra Nevada Range. During the 2001 Yosemite National Park research-planning workshop, the park was identified as having a special role in the earth sciences as a locus for trans-Sierra Nevadan studies and studies about how natural systems respond to global and regional climate change. Park environs also have the potential to be a barometer for hydrologic variations at spatial scales spanning the Sierra Nevada to the whole of western North America and at time scales ranging from hours to decades.

The presence of meteorological stations and streamflow gauging stations established almost a century ago in the Merced River basin have provided much of the incentive for studies that have demonstrated the remarkable potential of the park for earth science investigations. However, these relatively few observation sites now need to be augmented with more monitoring sites and additional parameters in both the Merced and Tuolumne River basins. To fulfill this need, meteorological, snowpack, and hydrologic conditions within the park are being monitored in more detail and greater consistency than in the past or elsewhere (at this scale) in the range.

The ability to interpret and predict streamflow, snowpack, flood, geochemical, and related ecological processes in Yosemite National Park has grown as a result of recent scientific research within its boundaries. With this increased ability comes the increased need for data, and particularly for real-time data, if this growing understanding is to be adequately translated into useful information for use by the Park, region, and Nation. Reaching the required level of monitoring is likely to be an incremental process as support, methods, and a track history of monitoring successes are developed that will justify the ultimate goals.

The initial components that will form the core of this monitoring effort include data on meteorology, hydrology, snow dynamics, and stream chemistry. In the near term, better communications are needed to harvest these data in real time. Presently they are transmitted via scheduled bursts of GOES telemetry or during infrequent manual downloads from memory contained in self-recording instruments. Ultimately, the aim is to embed many of these instruments into a near-continuous real-time network that will be ported to the Internet. Whereas the initial suite of physically based observations are those being implemented immediately or in the near future, the envisioned communications and other infrastructure will be designed to accommodate other physical or biological sensors and their data streams.

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## Climate and Wildfire in California and the Western United States<sup>1</sup>

**Anthony Westerling,<sup>2</sup> Alexander Gershunov,<sup>2</sup> Daniel Cayan,<sup>2</sup> Michael Dettinger,<sup>2</sup> Tim Barnett,<sup>2</sup> and Thomas Swetnam<sup>3</sup>**

It is well known that climate influences are pervasive in wildfire regimes in the western United States. In this research, wildfire histories and reconstructions for a variety of temporal and spatial scales are used to describe climate-wildfire relationships on annual to decadal time scales for California and the western United States. A 21-year gridded 1 x 1 degree monthly fire history compiled from Federal agency fire reports recreates the seasonality and interannual variability of wildfire in the western United States. A 75-year record of area burned aggregated by state for years 1916 through 1990 and regional fire scar indices for years 1700 to 1900 indicates strong links between variability in climate and wildfire regimes on decadal scales. Correlations between anomalous wildfire frequency and extent and the Palmer Drought Severity Index (PDSI) illustrate the importance of prior and accumulated precipitation anomalies for future wildfire season severity. Links to moisture conditions from the current and antecedent seasons' moisture conditions vary widely with differences in predominant fuel type, and can be exploited to estimate statistical models of seasonal wildfire area burned. The authors present statistical models reconstructing 18th- and 19th-century wildfire area burned using PDSI reconstructed from tree rings, which correlate strongly with regional fire scar indices for the same period, and a statistical forecast model for predicting area burned by ecosystem province in the western United States a season in advance.

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## The Southern Sierra Repeat Photography Project: Vegetation Changes over the Past 125 Years<sup>1</sup>

**Monica M. Bueno,<sup>2</sup> Nathan Stephenson,<sup>2</sup> Jon E. Keeley,<sup>2</sup> and Anne Pfaff<sup>2</sup>**

In this project, repeat photography was used to reconstruct historical changes in southern Sierra Nevada plant communities over the past 125 years. The study area encompassed foothill and forest plant communities from the Stanislaus River south to the Kern River. The primary focus was a comparison of vegetation changes in ponderosa pine forests and oak-chaparral communities of Kings Canyon with those already documented for Yosemite Valley. These two valleys share similar geologic and human histories, although Yosemite Valley has undergone extreme changes in drainage not experienced by Kings Canyon. In addition to qualitatively describing each of the photo pairs, some pairs were quantitatively analyzed using a simple, dot-grid-overlay counting method. The authors conclude that density and cover increases in the plant communities seen in Kings Canyon are not as dramatic as those documented for Yosemite Valley, raising questions about the roles of fire suppression versus hydrology in affecting vegetation changes in the latter.

Other, less detailed areas of inquiry included a look at changes in foothill chaparral communities and the chaparral-conifer ecotone and an examination of early vegetation conditions and subsequent change in giant sequoia groves. Landscape-level vegetation changes were evident in many of the photo comparisons.

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## Measuring the Effectiveness of Fuel Treatments in Changing Fire Behavior and Fire Effects during Wildfires<sup>1</sup>

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Direct observation and measurement of fire behavior as it passes through fuel treatment areas are the most direct ways to evaluate the effectiveness of fuel treatments. Concordant measurement of fuel conditions before the fire and fire behavior during the fire provide a means of evaluating which fuel metrics best relate to wildland fire behavior and improve fire behavior predictions. A rapid response team has been established to measure pre- and post-fire fuel conditions and fire behavior during wildland fire in areas with various fuel treatments and other past land management activities. During the fire season of 2002, the team is prototyping techniques for such research. For each fire event, the team: (1) rapidly obtains vegetation management history information; (2) obtains pre-fire aerial photographs; (3) collects data on pre-fire fuels condition; (4) measures fire behavior through sites where fuels have been measured; and (5) measures select immediate-post-fire effects and indirect measures of fire behavior. All information on weather, fire behavior, topography, fuels, fire suppression actions, and other pertinent information is captured and recorded, providing an overall context for the pattern of the fire. Preliminary results from one to three fires in 2002 will be available.

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## Ecological Impacts of Season of Prescribed Fire in a Sierra Nevadan Mixed Conifer Forest<sup>1</sup>

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Prescribed fire is an important tool for reducing fuels and restoring structure and function to forested ecosystems of the Sierra Nevada. Only a fraction of the acreage necessary for maintaining a natural fire return interval typically gets burned each year because of air-quality concerns in adjacent populated areas and the limited time before winter snows. Most prescribed burning is currently conducted in the fall to coincide with the normal historical fire period. This is also the time of year with the poorest air quality. Expanding the prescribed fire window to include early-season burns might reduce air-quality conflicts and allow more acres to be treated. However, the impact of early-season burning on many important ecosystem components is poorly understood.

Nine 15-hectare plots were established in Sequoia National Park in 2001. Three plots were burned in fall 2001, three plots were burned in June 2002, and three remained unburned (controls). Data on fuels, overstory tree density and composition, understory vegetation, small mammal and bird populations, bark beetles, root pathogens, and soil nutrient cycling were collected by researchers from the U.S. Geological Survey and other collaborators before the prescribed burns and are being collected post-burn. Initial data indicate a great deal of heterogeneity in fire intensity and subsequent tree mortality within both the early-season and late-season burn units. Multiple regression analysis showed that the proportion of the tree basal area composed of pines, together with the total basal area of all trees, explained 26 percent of the variation in crown scorch height in late-season burn plots. Areas with a high abundance of pines and more trees burned with the greatest intensity, whereas areas dominated by fir trees and having fewer trees burned with lower intensity. Data on tree mortality, fire damage, and area burned are presently being collected in the early-season burn plots. These data and comparisons between the early- and late-season burn treatments will be reported. Preliminary data indicate that early-season burns resulted in less fuel reduction and left more of the area unburned. These islands of unburned habitat may be important for post-fire recolonization by some plant and animal species.

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## **Preliminary Results from Hazardous Fuel Reduction at Yosemite National Park<sup>1</sup>**

**Kara J. Paintner<sup>2</sup> and Monica Buhler<sup>2</sup>**

Monitoring of mechanical fuel reduction paired with prescribed fires began at Yosemite National Park in 1996. Resource objectives include targets for total fuel loads and tree density. Ten plots have been installed using the National Park Service's Fire Monitoring Handbook. Each two-phase treatment starts with mechanical removal and piling of all ponderosa pine, incense cedar, and white fir smaller than 6 inches diameter at breast height (dbh) and burning of the piles. The treated area is then burned within 2 years. Seven plots have been thinned and had piles burned, and two plots have been burned. One- and ten-hour fuels increased after thinning and pile burning. Although the total fuel load was reduced, it remained well above target levels. The two burned plots showed significant fuel load reduction. Changes in fire behavior and tree mortality were modeled at the high end of burn prescription before and after thinning using crown mass. Before thinning, a stand could have surface and active crown fire, whereas after thinning, fire behavior changed to surface fire alone. Canopy base heights increased with thinning, whereas scorch height and mortality of larger trees decreased. This information is helping to refine project prescriptions, targets, and field evaluations for future work.

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## **Spatial Considerations in Fire Management: Importance of Heterogeneity for Maintaining Diversity in a Mixed Conifer Forest<sup>1</sup>**

**Monique E. Rocca,<sup>2</sup> Dean L. Urban,<sup>3</sup> and Jon E. Keeley<sup>4</sup>**

This study examines factors controlling fine-scale distributions of herbs, shrubs, and tree seedlings in Sierra Nevada mixed conifer forests. The goals of this project are to (1) determine the importance of within-fire heterogeneity in fire effects to maintaining plant diversity and (2) compare alternative fire-restoration strategies (spring prescribed fire, fall prescribed fire, and prescribed natural fire) in terms of their ability to create a heterogeneous environment that allows diverse suites of species to coexist. High resolution (1 meter) botanical and environmental data have been collected along 256-meter transects in the fire/fire surrogates plots and recent prescribed natural fires at Sequoia National Park. This study introduces a novel spatial statistical approach, wavelet analysis, to identify relationships between species and their environment while accounting for the fact that different environmental variables exert their influence on plants at different spatial scales. Preliminary results show that, in the absence of fire, understory species distributions are controlled by local variability in topography and soil moisture at scales greater than 64 meters. The authors are testing whether variability in fire effects leads to finer scale patterning of species distributions after fire. Once identified, the types and scales of fire-generated environmental variability that matter to plants can be incorporated into fire restoration plans.

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## Response to Management Strategies in Young-Growth Giant Sequoia Stands at Mountain Home State Forest<sup>1</sup>

Gary Roller<sup>2</sup> and Douglas D. Piirto<sup>3</sup>

Young-growth giant sequoia stands at Mountain Home State Forest were remeasured in 2001 to evaluate growth response to three silvicultural treatments: thinning, thinning followed by an underburn, and control. This is the third measurement in a continuing study that began in 1989. The California Department of Forestry and Fire Protection is providing funding for this Cal Poly study.

The current study is specifically evaluating (1) overall growth performance of treated giant sequoia stands, (2) understory plant response to the silvicultural treatments, and (3) fuel accumulations over the 12 years since the study stands were treated. All plots were precisely mapped using GPS technology, and photographs were taken from identified photo points during this third remeasurement effort.

Preliminary findings of this current Cal Poly study are available. This study is unique because very little research has been done to comparatively track the overstory and understory growth response of giant sequoia and associated flora following mechanical treatment and prescribed burning. The data and conclusions drawn from this study will be invaluable given the high level of interest in managing giant sequoia stands.

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## Thermally Driven Wind Systems and Boundary Layer Structure in Yosemite National Park<sup>1</sup>

Craig B. Clements<sup>2</sup>

Thermally driven wind systems are a common phenomenon in mountainous regions and are important in the transport of pollutants within the mountain boundary layer. Because population increases are expected in California's Central Valley, there is a need for a better understanding of the boundary layer structure in the Sierra Nevada. This will have important practical implications and provide improved forecasting of air pollution episodes that may lead to adverse health and visibility degradation in the region's national parks.

Observations of the wind and temperature structure made in two major valleys of Yosemite National Park are presented. Measurements were made during multiple campaigns from 1994 to 1998 using standard meteorological towers, an atmospheric profiling system, and pilot balloons. Results have shown that the atmospheric structure in the Yosemite region is complex and is rarely decoupled from the prevailing synoptic-scale flows. Vertical profiles of temperature in Yosemite Valley showed a strong and shallow inversion developing in the lowest 40 meters by morning. Above this layer, the valley atmosphere was nearly isothermal up to approximately ~700 m. above ground level. Winds within the inversion were extremely weak, but down-valley flows (approximately ~4-6 m s<sup>-1</sup>) persisted through the entire valley depth, suggesting that pollutants are easily transported from outside the region into the valley.

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## Fire and Invasive Plants in the Mixed Coniferous Forest<sup>1</sup>

Jon E. Keeley <sup>2</sup>

In the coniferous forests of Sequoia and Kings Canyon National Parks, species diversity is a function of fire severity and time period since fire. High-intensity fires create gaps that decrease canopy cover and increase light levels and nutrients for an ephemeral successional flora. Few species have persistent seed banks, so the time period since fire is an important determinant of colonization success. Complicating the picture of post-fire response is a highly significant interaction between fire severity and time period since fire for understory cover, species richness, and alien plant species richness and cover. Time was consistently a significant factor for these parameters, whereas fire severity was a significant factor only for species richness parameters. In general, understory was sparse the first year after fire, particularly in low-severity burns, and increased substantially several years after fire, particularly on high-severity burns. Both fire severity and time period since fire affected alien species richness and dominance. Coniferous forests had approximately one-third as many alien species as foothill oak savannas, and fewer than half of the species were shared between these communities. Some sites were largely free of alien species, whereas others had a significant alien presence that would present a challenge for fire restoration of these forests.

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## Impacts of Fuel Breaks on Alien Plant Invasion into Wildlands<sup>1</sup>

Jon E. Keeley <sup>2</sup> and Kyle Merriam<sup>2</sup>

This project addresses impacts of fuel breaks or defensible fuel-reduction zones on invasion by alien plant species into wildland areas that represent diverse fuel types, including shrublands, woodlands, and conifer forests. The authors are investigating this potential impact on Federal (Bureau of Land Management, National Park Service, and Forest Service), State (California Department of Forestry and Fire Protection), and local jurisdictions throughout California with multi-agency cooperation and support. The project has three objectives: (1) to inventory current floristic composition of fuel breaks in southern California, the central coast, the north coast, and Sierra Nevada and relate patterns of alien plant distribution to fuel break parameters, including construction age, past maintenance, vegetation modification treatment, proximity to roads, and other environmental variables; (2) to sample intensively belt transects perpendicular from fuel breaks into surrounding vegetation to determine the extent to which fuel breaks may act as source populations for the invasion of wildland areas (this sampling focuses on areas that have experienced fires within the past decade, because this is the time ecosystems are most vulnerable to invasion), and (3) to educate resource managers about the potential problems of invasive plants, both in terms of how they displace native vegetation and alter fire regimes and how fuel manipulations may be planned to minimize these impacts on natural landscapes.

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## Avian Response to Prescribed Burning in the Spring<sup>1</sup>

Karen Bagne,<sup>2</sup> John Rotenberry,<sup>3</sup> and Kathryn Purcell<sup>4</sup>

Fire is an important abiotic component in maintaining a diverse landscape in many regions including the Sierra Nevada. Exclusion of fire during the last century has altered natural systems, but in the past two decades, fire has been reintroduced through prescribed burning. Although prescribed fire returns an important natural process to the landscape, fire under human control can have features that are not consistent with fire regimes of the past. In particular, prescribed fires are often initiated during moist periods, such as spring, when many bird species are actively breeding. Preliminary findings from two years of data collected over 2 years in the Sierra National Forest are presented. Fires were set in early April and burned patchily on three of nine study sites. Territories of Hutton's Vireo were mapped and their breeding attempts monitored. Other target bird species were monitored as well. Tentative findings suggest that response to burning is similar to that during inclement weather events that can occur in the spring, and unburned patches within treated areas support habitat features required by specific species that could be otherwise be negatively affected. Other habitat features, such as snags, were monitored for changes in distribution and abundance resulting from prescribed fire as well as for use by cavity-nesting species.

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## Improving Fire Hazard Assessment at the Urban Wildland Interface: Case Study in South Lake Tahoe, California<sup>1</sup>

Lisa de Jong <sup>2</sup>

A fire hazard assessment was conducted on private, developed lots in South Lake Tahoe, a high-fire-hazard urban-wildland interface community in northern California. Fire hazard was assessed in terms of the minimum standards in the National Fire Protection Association's (NFPA) Standard 299 and homeowner choices relative to compliance with fire safety laws, construction of the home, and irrigation practices. In addition, researchers assessed the influence of noncompliant neighbors on a parcel's fire hazard. Results indicate that the overall fire hazard rating for the city is relatively low because of its good infrastructure: good roads, water, signage, and level of service. However, the citywide noncompliance rate for maintenance is 66 percent, the citywide noncompliance rate for defensible space is 86 percent when adjusted for small parcel size, and 57 percent of the parcels are noncompliant for both defensible space and maintenance. This study strongly suggests that homeowners in South Lake Tahoe rarely choose fire safety even though the city's fire infrastructure is effective. Furthermore, individual fire hazard will be underestimated if small lot size and homeowner actions are not taken into account. Analysis of compliance rates and homeowner choices will provide a more accurate estimate of individual lot fire hazard.

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## **Landscape Patterns of Pre-20th-Century Fire in the Kaweah Watershed, Sequoia and Kings Canyon National Parks<sup>1</sup>**

**Anthony C. Caprio<sup>2</sup>**

Knowledge of the spatial and temporal attributes of fire that occurred before Euro-American settlement (1700 to 1900), including fire size, is important for understanding ecosystem processes and for developing ecologically sound fire management objectives. Over the past decade, dendrochronology has been used to reconstruct fire histories for a network of sites in the Kaweah watershed on the west slope of the Sierra Nevada. This information provides a better understanding of fire across large spatial scales before Euro-American settlement within a complex landscape.

Sites extend from low-elevation conifer patches embedded in chaparral vegetation to high-elevation subalpine conifer forests. Striking differences in the fire regime between north and south aspects have been found, particularly at low- to mid-elevation conifer sites. Fire frequency on north aspects was less than half that observed on south aspects, with occurrence strongly linked to climate on north aspects. Reconstructions of fire size also show considerable variability. Some burns extended over much of the drainage and into adjacent watersheds. Fire size was also related to climatic variability, with large fires, particularly on north aspects, occurring more often during dry years. Such differences must have had significant influence on the biotic components and past dynamics of Sierra Nevada landscapes. This baseline information is being used in assessing the role of fire as an ecosystem process.

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## **Restoring Mixed Conifer Forests with Prescribed Fire: Monitoring to Assess Fuel Reduction and Stand Structure Objectives<sup>1</sup>**

**Mary Beth Keifer,<sup>2</sup> Jeff Manley,<sup>2</sup> and Karen Webster<sup>2</sup>**

Similar to wildlands throughout the Sierra Nevada, Sequoia and Kings Canyon National Parks experienced a disruption of the fire regime over the last century that altered forest conditions. Heavy surface fuels accumulated, stand density increased, and species composition shifted as a result of fire exclusion in forests where frequent fires had historically burned. Over the last 35 years, park managers and scientists have attempted to restore fuel and forest conditions using prescribed fire. A long-term fire effects monitoring program has documented changes in fuel load, stand structure and composition, and shrub and herbaceous vegetation composition before and after following prescribed fire treatment. Fuel-reduction objectives for initial prescribed fire treatment are met in all mixed conifer forest types. In the giant sequoia-mixed conifer forest, stand-structure-restoration objectives are met within 5 years after initial treatment; however, other mixed conifer forest types may need a second treatment with prescribed fire before restoration objectives are achieved. Once structural restoration objectives are met, process-related objectives for maintaining the natural fire regime become the standard for determining the success of the long-term prescribed fire program success.

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## Forest Litter Densities under Different Dominant Tree Species: A Factor Affecting Ground Fire Spread<sup>1</sup>

Kurt M. Menning,<sup>2</sup> John J. Battles,<sup>2</sup> Tracy L. Benning,<sup>3</sup> and Nathan L. Stephenson<sup>4</sup>

Long-lived conifer and several hardwood species dominate the mixed conifer forest in the southern Sierra Nevada. Historically, this forest experienced frequent, low-severity fires. The link between canopy species variability and fire behavior in a mixed forest is not well understood, however. Forest litter was sampled across 10,000 hectares in the Mineral King watershed to determine how dominant species affect litter density and fire behavior. Samples were sorted by canopy dominance. Litter under red fir (*Abies magnifica*) was the densest at 95 kilograms per cubic meter (kg/m<sup>3</sup>), followed by pine (*Pinus ponderosa*, *P. jeffreyi*, *P. monticola*, *P. contorta*: 76 kg/m<sup>3</sup>), white fir (*A. concolor*: 72 kg/m<sup>3</sup>), and the least dense, sequoia and cedar (*Sequoiadendron giganteum* and *Calocedrus decurrens*: 67 kg/m<sup>3</sup>). Density differences observed between red fir and both white fir and sequoia/cedar are significant. Fire spread rates and intensity have been calculated for the different litter densities given standard conditions. For example, white fir fire-spread rates (0.23 m/min) are more than double that of red fir (0.09 m/min). Intensity in white fir litter (38 J/m<sup>2</sup>min) is more than seven times that in red fir (5.3 J/m<sup>2</sup>min). Dominant canopy species appear to dramatically affect fire behavior in the mixed conifer forest.

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## Fire History of the Chaparral Zone in the Southern Sierra Nevada<sup>1</sup>

Jon E. Keeley,<sup>2</sup> Anne Pfaff,<sup>2</sup> and Pat Lineback<sup>3</sup>

Chaparral dominates a significant portion of the southern Sierra Nevada foothills, yet relatively little attention has been given to historical patterns of burning in these shrublands. Burning patterns for the 20<sup>th</sup> century were evaluated using a fire history database for the national parks; national forests; and lands administered by the Bureau of Land Management, California Department of Forestry and Fire Protection, and other jurisdictions in the foothills. Roughly half of the chaparral area has not recorded a fire during this time period, whereas some areas have experienced repeated fires. Spatial and temporal patterns of burning are presented. From these and other studies, there is reason to believe that, unlike southern California chaparral, these ecosystems may be at risk from fire exclusion.

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## Soil Moisture and Tree Seedling Distributions in a Mature Mixed Conifer Forest<sup>1</sup>

Andrew Gray,<sup>2</sup> Harold Zald,<sup>3</sup> and Malcolm North<sup>4</sup>

Distribution and abundance of tree seedlings and soil moisture in relation to stand structure were examined in an old-growth, Sierra Nevada mixed conifer forest. These measurements served as pre-treatment measurements for the forest-restoration experiment at the Teakettle Experimental Forest. Tree seedlings of the following species were found in declining order of abundance: white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), black oak (*Quercus kelloggii*), bitter cherry (*Prunus emarginata*), red fir (*Abies magnifica*), sugar pine (*Pinus lambertiana*), and Jeffrey pine (*Pinus jeffreyi*). Most species declined in abundance from closed-canopy areas to open areas to whitethorn ceanothus (*Ceanothus cordulatus*)-dominated areas. The exceptions were bitter cherry, which was most abundant in ceanothus patches, Jeffrey pine, which was most abundant in open areas, and black oak, which was most abundant in bedrock-dominated areas. For most tree species, areas with seedlings tended to have greater soil moisture than did areas without seedlings. Soil moisture declined steadily in the top 45 cm of soil during the growing season. Volumetric moisture values soon after snowmelt (mid-May) averaged 18 percent (ranging from 12 to 33 percent), and declined to 14 percent (ranging from 6 to 47 percent) by early July and 10 percent (ranging from 5 to 28 percent) by October. The high variability in soil moisture was associated with differences in topography and soil depth, and will likely be an important factor in determining the location and speed of vegetation response to disturbance.

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## Soil Nutrient Pools and Fluxes within a Mixed Conifer Forest: Implications for Ecological Restoration<sup>1</sup>

Heather E. Erickson,<sup>2</sup> Dale Johnson,<sup>3</sup> Patricia Soto,<sup>4</sup> and Carolyn Hunsaker<sup>5</sup>

Forest burning and thinning have obvious aboveground effects, yet effects on soil nutrient pools and fluxes are less apparent. As part of a large-scale forest-restoration experiment, baseline differences in soil resources were assessed for three dominant patch types (closed canopy, open canopy, and *Ceanothus*) within a mixed conifer forest. Organic and surface mineral horizon soils (0-15 cm) were collected from 54 patches (18 each for closed canopy, open canopy, and *Ceanothus*) and used to determine inorganic nitrogen (N), net N mineralization using laboratory incubations, and total pools of carbon (C) and N. *In-situ* fluxes of inorganic N and ortho-phosphorus (P) were also measured using resin lysimeters. For more than 2 years, *Ceanothus* showed greater nitrate-N and net N mineralization in organic horizons and ammonium-N and net N mineralization in mineral horizons than the other patch types. In contrast, the N and P fluxes measured by resin lysimeters did not differ significantly among the patches. In organic horizons, N pools were equally high in closed canopy and *Ceanothus* patch types, whereas C pools were greater under closed canopy. In mineral soils, N and C pools were greater under *Ceanothus* and open canopy than under closed canopy. Thus, restoration activities will likely affect the patch types uniquely.

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## Edge Effects in Mixed-Conifer Group Selection Openings: Tree Height Response to Resource Gradients<sup>1</sup>

Robert York,<sup>2</sup> John Battles,<sup>3</sup> and Robert Heald<sup>4</sup>

The group selection method of regenerating forests has been proposed as an alternative to clearcutting that potentially maintains economic viability while preserving ecosystem integrity. However, questions remain about the appropriate size of group-selection openings and the subsequent effects of edges on tree performance. In addition, there are questions about what resources may limit seedling growth within edge zones. To address these uncertainties in Sierra Nevada mixed conifer forests, replicated circular openings, ranging from 0.1 to 1 hectares (ha), were cleared in 1996 at the Blodgett Forest Research Station and planted with seedlings of six native tree species. After 3 years of growth, heights of all trees were measured and analyzed according to species, opening size, and location within the opening. To assess edge influences on tree height, differences in extension growth, predawn water potential, and light availability were measured along north-south transects for three species: giant sequoia (*Sequoiadendron giganteum*), ponderosa pine (*Pinus ponderosa*), and Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*).

The sequence of mean height from tallest to shortest on the basis of species was giant sequoia, incense cedar, Douglas-fir, ponderosa pine, white fir, and sugar pine. For all species combined, a tenfold increase in the area of the opening corresponded to a 34 percent increase in mean height. Trees were tallest on average in the north rows and shortest in the south rows. There was no difference in height between trees in the east and west rows. As expected, resource availability was greatest near the center and least near the edges, with northern edges receiving significantly more light than southern edges. In general, observed edge effects on sapling height growth were correlated with light and water supply. However, there were important differences between species in the nature of the co-limitation. Giant sequoia growth was most sensitive to light and water availability; together these variables explained more than 47 percent of the observed variation in giant sequoia height. In contrast, only light was a significant predictor of ponderosa pine performance. Douglas-fir heights were significantly related to both light and water, but there was more unexplained variability in the Douglas-fir model than in the other species. These highly controlled experimental group openings provide a standard reference for silviculturalists using the group-selection method of regeneration.

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## Mapping Sierra Nevada Vegetation Structure with Radar, Lidar, and Multispectral Fusion of Remote Sensors<sup>1</sup>

Jo Ann Fites-Kaufman,<sup>2</sup> Carolyn Hunsaker,<sup>3</sup> Peter Hyde,<sup>4</sup> Ralph Dubaya,<sup>4</sup> Leland Pierce,<sup>5</sup> Wayne Walker,<sup>5</sup> Birgit Peterson,<sup>4</sup> Bryan Blair,<sup>4</sup> Holly Hyde,<sup>2</sup> and Michelle Hofton<sup>4</sup>

At the present time, different subregions of the Sierra Nevada are mapped during different years and with different methods, contributing to inconsistent assessments of wildlife habitat, old-growth forest conditions, and fuel mapping and fire behavior analysis. The objective of this project is to develop a reliable, cost-effective process to evaluate and monitor wildlife habitat, old-growth forests, fuels, and potential fire behavior. Structural attributes evaluated have been large tree density (for old growth); tree height, crown base height, and crown bulk density (for crown fuels); and canopy cover and layering (for wildlife habitat). Remote sensors include radar, lidar, and Landsat™. Lidar and radar have been successful in mapping biomass, tree heights, canopy cover, large tree density, and canopy layering in other parts of the country but have not been tested in the diverse forests of the Sierra Nevada. Results to date show that lidar can map canopy heights well in the Sierra Nevada ( $R^2 = 0.75$ , SE 8.2 m), with increasing accuracy away from plot edges ( $R^2 = 0.93$ , SE 4.8 m). Canopy cover was estimated within 8 percent of measured values ( $R^2 = 0.81$ ). Biomass was also estimated successfully, with a RMSD of 251 Mg/ha ( $R^2 = 0.83$ ). Work with radar and fusion is under way.

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## Throughfall Deposition of Nitrogen in the Sierra Nevada as Determined by Ion Exchange Resin Columns<sup>1</sup>

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Nitrogen (N) deposition rates are high in some areas of California as a result of emissions from motor vehicles and agricultural activities. Total N deposition inputs are not known for most Sierra Nevada sites, largely because of the costs and technical difficulties of measuring the array of physical and chemical forms of nitrogenous pollutants. Recent studies demonstrate that monitoring throughfall N deposition using “passive” throughfall collectors is a viable method for estimating N deposition inputs at a large number of sites and is more practical than other techniques. This method uses ion-exchange resin columns that absorb inorganic N ions from throughfall or bulk deposition solutions. Throughfall deposition has been measured with passive collectors at 11 sites along a north-south transect in the Sierra Nevada. The importance of NH<sub>x</sub> emissions from agriculture in the Central Valley is evident from these data. The usefulness of this modified throughfall collection method is being evaluated, and the potential ecological impacts of N deposition will be discussed. It is proposed that ion exchange throughfall collectors can be used to determine N deposition thresholds at which key ecological effects, including water quality impacts, may occur in the Sierra Nevada.

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## Hydrologic Characterization and Implications of Forest Soil Disturbance at a Plot Scale: A Case Study in the California Sierra Nevada Mixed Conifer Zone<sup>1</sup>

Lucas W. Paz<sup>2</sup>

Physical and chemical environmental parameters were monitored in efforts to describe soil hydrology and plant characteristics on an artificially disturbed forest soil in the western Sierra Nevada Mountains. Disturbance treatment plots in the USDA Forest Service's Long Term Soil Productivity (LTSP) Research Program were assessed to characterize the impacts of forest removal, soil compaction, and removal of organic residue on soil moisture characteristics and related physiological processes related to soil water uptake and site hydrology. The primary investigation (1997–1999) assessed a broad range of soil parameters to determine the relative influence of organic residue and soil compaction on soil permeability and moisture capacity. *In-situ* volumetric soil moisture content was monitored throughout the 1998 growing season, and soil moisture characteristics were developed in the laboratory from data on soil water retention.

The results demonstrate how soil disturbance, typified by compaction and organic matter removal, can decisively alter the seasonal soil moisture regime and plant-available water. Significant changes in soil porosity and depth of organic residue were found to directly affect infiltration potential, soil water content, soil water potential and availability, soil temperature, soil aeration, and leaf water potential. A soil moisture balance for five soil disturbance treatments— (1) control/reference, (2) stem removal only, (3) whole tree and forest floor removal, (4) stem removal and soil compaction, and (5) whole tree removal, forest floor removal and soil compaction— was modeled using available soil moisture parameters established during the 1998 sampling period. Soil disturbance typified by a loss in porosity reduced soil moisture available to plants late in the growing season and resulted in reduced potential for translocation of moisture to deeper subsurface zones.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## California Land Cover Mapping and Monitoring: Creating and Maintaining Systematic and Accurate Land Cover Maps<sup>1</sup>

Chris S. Fischer,<sup>2</sup> Mark Rosenberg,<sup>2</sup> Lisa M. Levien,<sup>3</sup> and Brian D. Schwind<sup>3</sup>

An accurate depiction of the spatial distribution of habitat types within California is required for a variety of land management planning purposes. The relative extent of vegetation or habitat types in different ownerships, watersheds, and counties has major implications for policies and strategies that can be ownership specific. To conduct the "Forest and Range 2002 Assessment," vegetation extent, composition, and structure information from numerous sources were combined into a format compatible for use within a Geographic Information System (GIS), which allows statistical analysis as well as numerous spatial modeling efforts to address timber, range, fire, development impacts, and wildlife habitat issues.

The California Land Cover Mapping and Monitoring Program (LCMMP), a cooperative program between the USDA Forest Service and the California Department of Forestry and Fire Protection, creates seamless data from Landsat Thematic Mapper™ satellite imagery. Vegetation data establish existing conditions from which impacts of changes over time are assessed. Data are captured using automated, systematic procedures that can efficiently and consistently map large areas at low cost. Regionally, monitoring can identify patterns and critical causes of change. Locally, monitoring can assess county land-use policies, identify areas of insects or disease problems, or assess the extent and impact of timber harvest in a watershed.

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# The Response of Cheatgrass (*Bromus tectorum L.*) and Native Flora to Ecological Manipulations in the Yellow Pine–Mixed Conifer Forest<sup>1</sup>

Thomas W. McGinnis,<sup>2</sup> Jon E. Keeley,<sup>2</sup> Matt Brooks,<sup>3</sup> Robert Sanford,<sup>4</sup> and Jayne Belnap<sup>5</sup>

The earliest settlers brought weeds with them to the West; one of the most persistent weeds to arrive on western rangelands is cheatgrass. Burned areas are quickly colonized by cheatgrass as isolated satellite populations, which then spread their seeds into these newly disturbed lands. Although areas west of the Sierra Nevada have long been converted to non-native annual grasses, such as *Bromus* and *Avena*, cheatgrass commonly invades east of these mountains in the Great Basin; the forests in between were once thought to be immune to annual grass invasions. Although cheatgrass has been known to exist along roads and trails in the Sierra Nevada for some time, widespread invasions in the yellow pine forest were unknown. Today, large expanses of these forests are becoming carpeted by cheatgrass. One such area of widespread invasion is the Cedar Grove area of Kings Canyon National Park, where this study takes place.

Because the disturbance factors that trigger cheatgrass invasions in these forests are unknown, measures to prevent its invasion are also unknown. In 408 randomly assigned five-by-five-meter test plots (six replicate sites), researchers are intensifying several disturbance factors to determine how each affects cheatgrass and native plant cover. Plots either remain unburned or are burned in one of three burning seasons. Before and after each burning season, soils are tested to see how temperatures affect soil nutrients. Temperatures are monitored above- and below-ground using six thermocouples per plot. Plots are assigned one of the following manipulations: no addition, pine litter addition, 50 percent shade, added or reduced nitrogen, added or reduced phosphorus, cheatgrass seed addition, or native seed addition. Although no manipulation following the low-intensity burns in fall 2001 resulted in the elimination of cheatgrass, it is expected (after observing the unmanipulated forest surrounding these plots) that the addition of five centimeters of pine needles, a treatment added in 2002, will eradicate cheatgrass. Other plant cover changes will be assessed relative to each disturbance factor.

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## Reconstruction of Historical Vegetation Distributions in the Sierra Nevada Using Government Land Office Survey Records<sup>1</sup>

Holly Hyde,<sup>2</sup> Jo Ann Fites-Kaufman,<sup>2</sup> Michael Barbour,<sup>3</sup> and Dave Weixelman<sup>2</sup>

Most reconstructions of historical vegetation in the Sierra Nevada have focused at the site scale. The objective of this study was to reconstruct patterns of tree species composition at the landscape scale. Historical relationships of composition with environmental gradients were of specific interest. This study utilized government General Land Office (GLO) survey records, which represent a systematic grid of points at section corners, collected in the late 1800s. At each section corner, data were recorded in a manner that resembles the point-center-quarter procedure. GLO data were examined across three elevational gradients in the central and southern Sierra Nevada, encompassing modern foothill, ponderosa pine, mixed conifer, and red fir forests. A community classification (TWINSPAN-based) resulted in 15 community types. Based on canonical correspondence analysis, elevation was the primary environmental influence (80 percent of variance), followed by topographic position and aspect. At elevations below 1,000 meters, oak was dominant (78 percent frequency), but pine comprised 24 percent of the basal area. Pine species represented 60 percent and 49 percent of the total basal area in low elevation (1,000 to 1,500 meters) and mid-elevation (1,500 to 2,000 meters) areas. At low elevations, oaks shared dominance (37 percent frequency) with pines, whereas at mid-elevations white fir comprised 16 percent of the basal area and 26 percent of the stems.

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## Continuous Forest Inventory in California: New Design Provides Rich and Timely Data for a Variety of Applications<sup>1</sup>

Karen Waddell<sup>2</sup> and Sally Campbell<sup>3</sup>

The Pacific Northwest Research Station's Forest Inventory and Analysis (PNW-FIA) program inventories public and private forestlands in California, Oregon, Washington, Alaska, and the Pacific Islands. In the past few years, PNW-FIA has implemented a new nationally consistent, four-point design across all ownerships. Inventory plots are now sampled on an annual basis, instead of on the traditional 10-year cycle. PNW-FIA databases contain a diverse array of unbiased estimates for many attributes of California's forest ecosystems. PNW-FIA staff and collaborators are actively working on a variety of summary reports, analyses, and research studies, and many projects either focus on or are relevant to forests in the Sierra Nevada. Examples of ongoing projects include a study of California's hardwoods, sudden oak death, fuel treatment feasibility and acceptance, and an update of forestland statistics. This poster highlights details of the new inventory design, summarizes the type of data being collected and calculated, and describes some of the projects that use either current or past inventory information.

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## Characterizing the Light Regime of Different Mature Forest Stand Structures<sup>1</sup>

Rolf Gersonde<sup>2</sup> and Kevin L. O'Hara<sup>3</sup>

Successful regeneration of mixed conifer forests depends on conditions suitable for survival and growth of all desired species. The light regime under the forest canopy strongly influences the competitive interaction of regenerating species and can be manipulated by the forest manager through density management of the overstory. The light model tRAYci was used to calculate light transmission through canopies of different densities, overstory species, and spatial structure: seed tree, shelterwood, small group selection, and closed canopy.

Average light intensity at the forest floor was lowest in the closed canopy stand (basal area of 125 square feet per acre), followed by the shelterwood (basal area of 75 square feet per acre), small group selection (0.25-acre opening) and was highest in the seed tree stand (basal area of 17.4 square feet per acre). Light intensity was significantly lower at the forest floor when the overstory was composed of white fir (*Abies concolor*) than when it was composed of ponderosa pine (*Pinus ponderosa*). Variability of incident light in the transition zone increased with stand density. Variation in aspect caused a small but significant change (2.7 percent) in average light intensity at the forest floor. Data from this study showed differences in the vertical profile of light transmission through the canopy. Light profiles in all stands showed a homogeneous light regime below the foliated crown space (dim light zone, 0–15 meters) and rapidly increasing light transmission in the transition zone (15–30 meters).

Light intensity and vertical position of the light gradient have consequences for the availability of light to understory trees. Characterizing the available light resources under various overstory structures can facilitate development of management guidelines for regeneration of mixed conifer stands.

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## Tree Growth and Death in the Sierra Nevada<sup>1</sup>

Nathan L. Stephenson,<sup>2</sup> Phillip J. van Mantgem,<sup>3</sup> and Peggy E. Moore<sup>4</sup>

Models suggest that forest characteristics are profoundly affected by the relationship between tree growth rate and probability of death. Yet little is known about the relationship, or how environmental changes might affect it. In particular, “gap” models of forest dynamics rely on two untested assumptions: (1) causes of tree death fall into two groups: those independent of and those dependent on growth rate, and (2) the only way environmental changes affect probability of death is indirectly, by altering growth rate. These assumptions were examined by tracking the growth and survival of 10,691 trees, recording 775 deaths by cause. Contrary to assumptions, no specific cause of death was independent of growth rate. However, the strength of the relationship between growth and death differed significantly among causes. White pine blister rust was found to increase probability of death in *Pinus lambertiana* growing at all rates, demonstrating that changes in probability of death can be either growth mediated, as assumed in gap models, or direct, resulting from a change in the nature of the relationship between growth rate and probability of death. The findings from this study have implications for understanding and predicting the potential effects of environmental changes on tree mortality.

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## **A Contrast in Vital Rates: Life Table Projections for *Abies concolor* and *Pinus lambertiana* in a Sierra Nevada Mixed Conifer Forest<sup>1</sup>**

**John J. Battles<sup>2</sup> and Frieder G. Schurr<sup>3</sup>**

The demography of *Abies concolor* (ABCO) and *Pinus lambertiana* (PILA) was examined in a mature mixed conifer forest in the Sierra Nevada. Size-classified matrix models were constructed and then elasticity analysis applied to determine which vital rates (survival, growth, and fecundity) were the most important determinants of population change. Survival of canopy-sized ABCO averaged 0.985 per year for the past 30 years. Fecundity (measured as the number of germinants produced) over the past 5 years averaged 154 germinants per canopy tree year. The projected population growth rate for ABCO was 1.007, indicative of a slowly growing population. In contrast, PILA, was projected to decline, with a growth rate equal to 0.985. Adult survival, particularly in the codominant size class, was much lower for PILA than for ABCO (0.939). PILA fecundity averaged less than 10 germinants per tree year. Changes in the PILA population were extraordinarily sensitive to the survival rate of canopy trees (elasticity = 0.856). The ABCO population was also dependent on adult survival (elasticity = 0.506), but understory tree survival was another important component (elasticity = 0.371). These projections support the contention that the Sierra Nevada conifer forests are communities currently ruled by nonequilibrium dynamics. Both fire suppression and an introduced pathogen contribute to the uncertain future of these forests.

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## **Overview of the Kings River Project<sup>1</sup>**

**Carolyn Hunsaker<sup>2</sup> and Nancy Fleenor<sup>3</sup>**

The Kings River Project seeks to determine whether desired landscape conditions that create forest stand structures that mimic historic forest conditions and processes can sustain wildlife populations and stream ecosystems while providing forest products. The Sierra National Forest and the Pacific Southwest Research Station are working together on design, implementation, and analyses for the Kings River Project. Since 1994, the Kings River Project has been implementing a management system of uneven-aged group selection and a program of prescribed fire within two adjacent watersheds comprising 150,000 acres. Current research studies include stream ecosystems and watershed condition, demography of the California spotted owl, variations in the abundance and productivity of forest birds, occurrence and distribution of fishers, and long-term soil productivity. The project is examining the response of these ecosystem elements to timber harvest and prescribed fire.

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## Edge Effects of Group-Selection Harvest on an Old-Growth Forest in the Sierra Nevada<sup>1</sup>

Zachary E. Kayler,<sup>2</sup> Lucas B. Fortini,<sup>2</sup> and John J. Battles<sup>2</sup>

Potential edge effects associated with group-selection harvest were measured on the northern border of an old-growth Sierra Nevadan conifer forest. Changes in resource availability (light, water, and seedbed) and plant composition (abundance and richness) were quantified across transects that spanned from the interior of old-growth forest through group-selection openings. Researchers found a steep change in resource availability: plots in old-growth forests and on edges of the group opening were shadier (8 percent versus 50 percent full sun), had more water in the top 20 cm of soil, and had less exposed mineral soil. These three environmental variables explained more than one-third of the observed variation in species composition. Both parametric and non-parametric multivariate analyses confirmed that there are two distinct plant communities, old-growth and group selection, with no indication of an ecotonal community along the edge. Understory plant species richness normalized to a total area sampled of 0.25 hectare was significantly greater in the group-selection (59 species) than in the old-growth forest (42 species). Non-native plant species accounted for a similar proportion of total species richness in both community types (four percent). *Chimaphila umbellata* was a reliable indicator species of old-growth forest conditions.

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## A Comparison of Ectomycorrhizal Response to Group-Selection Cutting on Two Mixed Conifer Species, *Pseudotsuga menziesii* and *Pinus ponderosa*<sup>1</sup>

Anna L. Levin,<sup>2</sup> John J. Battles,<sup>2</sup> and Thomas D. Bruns<sup>2</sup>

Group selection has been proposed as an alternative to clearcutting, but the impact on a crucial component of seedling health, ectomycorrhizal fungi (EMF), has not been examined. Seedlings of *Pseudotsuga menziesii* (PSME) and *Pinus ponderosa* (PIPO) were planted in one-hectare groups along a gradient from intact forest to opening at Blodgett Forest to (1) determine whether EMF colonization rates and species richness decrease with increasing distance from forest edge and (2) examine whether patterns in EMF communities differ between the two conifer hosts. For PSME, a significant reduction in EMF colonization and richness occurred with distance from the edge. The colonization rate for PSME seedlings in the forest was nearly 100 percent, with 4.8 EMF species per seedling, but decreased to an average of 58 percent colonization and 3.2 species per seedlings in the opening. In contrast, there were no edge-related differences in EMF colonization or richness for PIPO: the colonization rate was 90 percent, with approximately four EMF species per seedling, regardless of distance from forest edge. The reduction in EMF colonization and richness found on PSME in the opening suggest that establishment problems observed for PSME in large clearcuts may be related to the mycorrhizal status of seedlings.

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## Growth of Conifers Planted under a Shelterwood<sup>1</sup>

Robert C. Heald<sup>2</sup> and Jennifer K. Prentiss<sup>2</sup>

This study compares the survival and growth of conifer seedlings planted in various forest floor conditions under a shelterwood. Planting under a shelterwood is indicated when some desirable seed trees are not available, for example sugar pine (*Pinus lambertiana*) resistant (Rr) to white pine blister rust (*Cronartium ribicola*). At Blodgett Forest Research Station, a shelterwood harvest retained 12 seed trees per acre. Tractor-pile site preparation left burned piles as far away from shelterwood trees as possible. These locations become the best potential growth sites and the least likely to be stocked by natural seed fall. Fifty burn piles were planted with Rr sugar pine, Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), giant sequoia (*Sequoiadendron giganteum*), and incense cedar (*Calocedrus decurrens*) in ash, burn pile edge, and adjacent unburned area. After 5 years, diameter and height of each planted seedling were recorded. Shrub species, percent cover, and height were measured on mil-acre plots at each planted tree. Average diameter and height of both giant sequoia and ponderosa pine were greater than that of sugar pine, incense cedar, and Douglas-fir. Shrubs grew more vigorously along the edge of burned piles than in either ash or mineral soil, whereas trees grew faster when planted in ash.

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## Sequoia Pruning Timing Study<sup>1</sup>

Robert C. Heald<sup>2</sup> and Wm. David Rambeau<sup>2</sup>

Young-growth giant sequoias (*Sequoiadendron giganteum*) have potential to produce high-value clear redwood products but exhibit virtually no self-pruning. Average branch diameters at age 10 years range from 1 to 3 centimeters as spacing increases from 2 to 6 meters. Whereas planting density affects stem diameter and height, branch sizes remain well within the range that can easily be pruned using standard tools. Little is known about the effects of pruning on growth, epicormic branching, heartwood formation, and stem taper of giant sequoias.

This study was located in an existing sequoia density study at Blodgett Forest Research Station. Sequoia trees were pruned over a wide range of tree sizes and pruning intensities throughout a calendar year. Measurements of 500 pruned and control trees included tree height, stem diameter at several heights, existing epicormics, heartwood, branch recession, crown radius, and branch diameters. After pruning, sequoia trees produced epicormic branches only at pruned branch collars. Sequoia trees pruned from October through May frequently developed epicormic branches. These sprouts first appeared in conjunction with new leaf development the following June. Sequoia trees pruned from June through September rarely developed epicormic branches. Frequency, quantity, and length of epicormic branches produced increased as pruning intensity increased.

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## Mixed Conifer Plantation Growth<sup>1</sup>

Robert C. Heald<sup>2</sup> and Nadia Hamey<sup>2</sup>

Although little information is available, some observers have speculated that mixed species plantations provide greater wood productivity, increased visual quality, and more wildlife species diversity than single species plantings. This study examined a variety of cultural treatments in native mixed conifer plantations at Blodgett Forest Research Station. For site preparation, all woody material other than sawlogs was masticated and left in place following harvest. The sites were planted in April 1992 with an equal mix of *Pinus ponderosa*, *Pinus lambertiana*, *Calocedrus decurrens*, *Abies concolor*, *Pseudotsuga menziesii*, and *Sequoiadendron giganteum* on 2.5-meter square spacing. The stumps of harvested *Quercus kelloggii* sprouted vigorously the same spring. In a random block design, six replications each of hand weeding, herbicide, and a no-treatment control were applied during the second growing season. An additional 18 similar treatment areas were exposed to grazing by range cattle. All treatments were thinned after the 5th-year measurement to a residual density averaging 800 trees per hectare. Seasonal range cattle grazing (and the exclosures) continued throughout the study. After 10 years, tree heights and diameters varied significantly by species, treatment type, and total shrub cover. Combined grazing and weeding or grazing and herbicide plots developed the least shrub cover and largest trees.

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## Effects of Planting Density on Early Growth of Giant Sequoia (*Sequoiadendron giganteum*)<sup>1</sup>

Robert C. Heald<sup>2</sup>

This study measured 2,086 giant sequoia seedlings planted at spacings of 7 to 20 feet. Giant sequoia show remarkably early and extensive effects of competition. Spacing substantially affects early height growth of sequoias. By 10 years, trees at wide spacing distance were showing 60 percent wider annual diameter growth and 50 percent higher annual height growth than trees at half each respective spacing. During the 9<sup>th</sup> and 10<sup>th</sup> growing seasons, 27 trees were carefully measured every 2 weeks from April through October. Total season height and diameter growth generally increased with increasing spacing. Trees at wide spacings added approximately 1 inch in diameter and 2.6 feet in height, approximately 40 percent more growth than trees at half their respective spacings. One explanation for the unusual response is that both height and diameter growth are limited by soil moisture depletion during the late growing season. Sequoia trees at all spacings had observable diameter growth by mid-May. New leaf development and branch and height growth were not visible until mid-June. Both height and diameter growth simultaneously ceased by September. This contrasts with typical conifer patterns of an early spring start and short duration of height growth followed by more gradual and longer-duration secondary growth of the cambium.

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## The Kings River Project: Small Stream Ecosystem Variability and Response to Fire<sup>1</sup>

Carolyn Hunsaker<sup>2</sup> and Sean Eagan<sup>2</sup>

The quality of aquatic and riparian ecosystems is a function of their condition and the integrity of adjacent uplands in their watershed. Although small streams make up a large proportion of the overall stream network, our knowledge of how they function is still limited. The Kings River Experimental Watershed Project was initiated in 2000 to quantify the variability in characteristics of small-stream ecosystems and their associated watersheds. Forest managers want to understand the effects of fire and fuel reduction treatments on riparian and stream physical, chemical, and biological conditions. Two mixed conifer study sites are being developed at elevations of 1,700 to 2,400 meters. Data will be gathered for at least a 3-year reference period, and then fire and harvesting treatments will be applied. After the treatments, data will be gathered for at least 7 years. Each site will have a control watershed that receives no treatments, a watershed that is burned, a watershed that is harvested, and a watershed that is both burned and harvested. The watersheds range from 80 to 150 hectares, a size that can be consistently treated. Data relative to stream discharge, water chemistry, sediment loads, and invertebrate composition have been collected for water years 2000 and 2001.

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## Seed Fall and Seedling Recruitment in Mixed Conifer Forests of the Sierra Nevada<sup>1</sup>

Jon E. Keeley<sup>2</sup> and Philip van Mantgem<sup>2</sup>

Forest regeneration is likely a sensitive indicator of global change perhaps evident in patterns of cone initiation, seed production, and seedling recruitment. Regeneration, however, is complicated by a limited understanding of how current conditions control these parameters. Seedling recruitment strategies are poorly understood because of marked limitations in the temporal and spatial scale of study. The Sierra Nevada Global Change Project can contribute significantly because of its long-term focus across a broad elevational range, from 1,500 to 3,000 meters, in the southern and central Sierra Nevada. Analysis along this gradient shows that elevation is an important predictor of conifer seedling density, best illustrated by a simple exponential decay model. Elevational effects are only weakly evident in firs but prominent in pines. Not surprisingly, in these largely undisturbed forests, white fir (*Abies concolor*) dominates the recruitment, and ponderosa pine (*Pinus ponderosa*) is barely represented. Incense cedar (*Calocedrus decurrens*) and sugar pine (*P. lambertiana*) recruitment patterns are broadly similar to that of white fir. Evidence of successful understory recruitment and establishment in the understory by sugar pine suggests limited fire dependence in this pine species. Although white fir is capable of successful recruitment in the understory of undisturbed forests, it also recruits heavily into burned sites, suggesting that the often-used term “fire-intolerant species” may be inappropriate.

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## **Influence of Light and Soil Moisture on Sierra Nevada Mixed Conifer Forest Understory Community<sup>1</sup>**

**Malcolm North,<sup>2</sup> Brian Oakley,<sup>3</sup> Rob Figener,<sup>4</sup> Andrew Gray,<sup>5</sup> and Michael Barbour<sup>4</sup>**

Site conditions affecting herb and shrub dynamics in Sierra Nevada forests have not been well studied. In an old-growth, mixed conifer forest, the understory community and its distribution in relation to microsite conditions was examined. Canopy cover was also measured using three common field methods to compare the assessment of conditions influencing herb and shrub cover. The objectives of this study were to (1) ordinate the understory plots to assess indirect environmental gradients influencing community structure; (2) test for significant differences in soil moisture, light, canopy cover, and coarse woody-debris or litter-depth conditions between associations, (3) identify individual herbs and shrubs strongly correlated with specific site conditions; and (4) identify which measure of canopy cover is most strongly correlated with understory cover. Communities in the mixed conifer understory were strongly influenced by soil moisture, coarse woody debris, litter depth, and intensity of understory light. There appear to be threshold soil-moisture and canopy-cover levels below which herbs are rare or absent. Spherical densiometer and moosehorn canopy cover measurements were found to be poor indicators of understory conditions because they did not account for canopy openings and sun angle. In the southern Sierra Nevada, hemispherical photographs are needed to predict understory dynamics in response to fire and thinning disturbances.

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## **Differences in Stand Structure and Pattern of Sierra Nevada and Pacific Northwest Old-Growth Forests<sup>1</sup>**

**Malcolm North,<sup>2</sup> Jiquan Chen,<sup>3</sup> and Brian Oakley<sup>4</sup>**

Species composition, structure, spatial pattern, light, and soil moisture were compared between two old-growth forests: closed-canopy Pacific Northwest western hemlock/Douglas-fir at the Wind River Canopy Crane Facility and patchy Sierra Nevada mixed conifer at the Teakettle Experimental Forest. The Teakettle forest exhibits a lower basal area than Wind River forest. Basal area at Teakettle is concentrated in tree groups, 30 to 50 meters in diameter, with these groups having a similar basal area and higher density than at Wind River. At Wind River, large trees are regularly spaced from 0 to 15 meters, and shade-tolerant and intolerant species are “repelled,” whereas at Teakettle, large trees are randomly distributed from 0 to 80 meters, and shade-tolerant and shade-intolerant species are “attracted.” Average understory light is 15 times higher at Teakettle than at Wind River. At Teakettle, there is no canopy stratification by shade tolerance, and light in openings may inhibit horizontal stem pattern, producing persistent gaps. This suggests that mixed conifer forests may have a minimum canopy cover threshold for tree survival. Higher cover needed for tree establishment and growth may override stem repulsion produced by tree competition for growing resources. These findings indicate that stand management that reduces canopy cover to release regeneration should be applied with caution in the southern Sierra Nevada.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## Effects of Logging and Prescribed Fire on Fecundity and Seed Dispersal of Sierra Nevada Conifers<sup>1</sup>

Ruth Ann Kern<sup>2</sup>

Seed rain is being monitored in experimental-forest treatment plots to investigate the effects of thinning and prescribed fire on seed production and seed dispersal distances of Sierra Nevada conifers. Eighteen 1-hectare forest research plots, established in the Teakettle Experimental Watershed in the Sierra National Forest, have been manipulated in a 2 × 3 factorial design (fire or no fire; shelterwood thinning prescription, California spotted-owl thinning prescription, or no thinning) with three replicates of each treatment. Twenty-five seed traps (0.25 m<sup>2</sup>) have been installed on a 25-meter grid in each of the 18 plots. Logging and prescribed fire treatments were completed in 2001, and seed traps were installed in early summer 2002. Data from this long-term study will be used to understand individual and cumulative effects of thinning and prescribed burning on seed production and seed dispersal distances of white fir, red fir, sugar pine, Jeffrey pine, and incense cedar.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## Effects of Fire on Soil Nitrogen and *Frankia* Associated with Patches of the Actinorhizal Shrub *Ceanothus cordulatus*<sup>1</sup>

Brian Oakley,<sup>2</sup> Malcolm North,<sup>3</sup> Brian P. Hedlund,<sup>4</sup> James T. Staley,<sup>4</sup> and Jerry F. Franklin<sup>5</sup>

The largest inputs of nitrogen (N) occur via symbiotic N-fixation, yet N-fixing plants are usually limited to the early stages of post-disturbance succession. Sierra Nevada forests, however, are an interesting exception because N-fixing *Ceanothus* spp. can dominate the understory even in mature and old-growth forests, possibly because of fire maintaining an open canopy. This study focused on two key questions: (1) are soil N levels associated with patches of *Ceanothus* significantly enriched relative to surrounding areas, and if so, does this effect persist after fire? And (2) does fire reduce the number of *Frankia* in the soil or select for particular strains of *Frankia*?

A burn experiment was conducted to determine whether soil beneath *C. cordulatus* patches represents N “resource islands” and whether any N enrichment persists after fire to potentially influence forest regeneration and spatial patterning. *Ceanothus* patches are enriched relative to other patch types in total and mineral N before fire, and this effect largely persists after fire. Vigorous resprouting (particularly in plots burned at low intensity) and lower C:N ratios in *Ceanothus* patches will likely continue this trend into the future. Fire appears to have little effect on *Frankia*, and regional *Frankia* diversity is low; however, distinct strains can be found at the scale of major biogeographic divisions.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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# Fire and Fuels Management, Landscape Dynamics, and Fish and Wildlife Resources: An Integrated Research Plan on the Plumas and Lassen National Forests<sup>1</sup>

**Peter Stine,<sup>2</sup> John Keane,<sup>2</sup> Malcolm North,<sup>2</sup> Scott Stephens,<sup>3</sup> Doug Kelt,<sup>4</sup> Dirk Van Vuren,<sup>4</sup> Michael Johnson,<sup>5</sup> Geoff Geupel,<sup>6</sup> and Mary Chase<sup>6</sup>**

An integrated series of studies is intended to evaluate land management strategies that have been designed to reduce wildland fire hazard, promote forest health and ecosystem stability, and provide economic benefits across managed forest landscapes, such as those found on the Plumas and Lassen National Forests. The research program is organized around four principal issues: (1) efficacy of selected combinations of defensible fuel profile zones (DFPZs) and area fuel treatments to reduce the extent and severity of wildland fires; (2) effects of group selection as a silvicultural tool on various forest elements and conditions; (3) cumulative effects of management regimes on landscape dynamics, such as forest structure, composition and succession across time and space; and (4) species-specific responses to landscape changes resulting from different forest management regimes. At the most basic level, the objective of the proposed research is to address, in a coordinated effort, an array of related ecological questions, and thereby provide empirical data to inform future management decisions.

At this time, the research program is focusing on five “modules” of response variables. These include (1) vegetation; (2) fire and fuels; (3) density, reproductive success, and diet of the California spotted owl; (4) small mammal distribution, abundance, and habitat relations; and (5) landbird distribution, abundance, and habitat relations. The critical interplay of space and time, particularly over larger, longer, and more diverse frames of reference than most ecological research programs have attempted in the past, is a major objective of this research program. The program is designed to assess the integrated response of key variables across broad landscapes over relatively long periods of time. Although some questions can be addressed by substituting space for time or by inductive reasoning from short-term, small-scale studies to broader landscapes, other questions unavoidably require a longer-term research commitment over large landscapes.

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## The Kings River Project: Historic Stand Structures, Forest Processes, and Vegetation Manipulation<sup>1</sup>

Carolyn Ballard<sup>2</sup> and Ramiro Rojas<sup>2</sup>

The Kings River Project is intended to create an experimental framework at a watershed scale to examine the response of an array of ecosystem elements to uneven-aged, small group selection and prescribed fire. Structural variation caused by timber harvest or mechanical thinning is designed to be fine grained, mimicking small-scale natural disturbances, such as those caused by a few acres of high-intensity crown fires within a matrix of frequent low-intensity fires. The systems initiated for the study minimize the use of forest zoning, emphasize multi-resource objective management on homogenous areas in a watershed, and utilize the uneven-aged management system to program vegetation manipulation. Group selection and silvicultural practices are used to mimic effects of frequent, low-intensity fire. Fuels treatments are concurrent with silvicultural activities, and harvest practices followed by slash piling, mastication, and prescribed burning are used to create openings. Defensible fuel profile zones are used within the wildland urban intermix to aid wildfire suppression. Prescribed fires, alone or in conjunction with silvicultural treatments, are being conducted to improve ecosystem condition and return fire to the forest as a natural disturbance process.

The Kings River Project defines desired forest conditions as those stand structures and processes found in the area in the 1850s. Historic forest structures and processes were investigated to determine the range of variability found within the project watersheds. A vision of desired stand structures and processes was developed from historic photos, descriptions from trained observers from the early 1900s, literature from similar neighboring forests, data collected from the early 1900s, and examinations conducted within the project area. This analysis determined that although stand structures were variable, generalizations can be made on the basis of on forest type, aspect, and slope. Frequent low-intensity fire resulted in uneven-aged structures across the ponderosa pine and mixed conifer types. High variability existed between and within stands. Understory fuel loading was low. Regeneration occurred episodically rather than continuously. Stand density was characterized by widely spaced crowns. Many forest stands within the project area were characterized by unoccupied growing space. In contrast, high crown density and infrequent fires characterized the true fir stands. Fire often caused stand replacement along the transition from pine-dominated stands to fir-dominated stands. Forest exams for 1912 and 1917 found little evidence of insect mortality.

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## Inventory and Risk Assessment of Aspen on the Eagle Lake Ranger District, Lassen National Forest<sup>1</sup>

Bobette E. Jones<sup>2</sup> and Tom H. Rickman<sup>2</sup>

An aspen (*Populus tremuloides* Michx.) inventory and risk assessment project is being conducted on the Eagle Lake Ranger District, Lassen National Forest. This project was initiated in response to observed declines in health and distribution of aspen stands on the Eagle Lake Ranger District. Objectives of this project are to (1) produce a complete inventory of aspen on the Eagle Lake Ranger District by 2003 and (2) develop stand-specific management recommendations and include these recommendations as actions analyzed in site-specific environmental documents under the National Environmental Policy Act (NEPA) so that the required restoration activities can take place.

Each aspen stand is delineated using Global Positioning Systems and assessed on the basis of risk factors identified by Bartos and Campbell (*Decline of quaking aspen in the interior West, examples from Utah*, 1998). Management recommendations are based on observed stand conditions. To date, 312 stands totaling 592 hectares, with a mean stand size of 1.9 hectares, have been inventoried. Eighty-seven percent of the stands have received a high or highest priority rating, indicating that aspen are at risk. Aspen is considered a keystone species, and aspen communities are critical for maintaining biodiversity in Western landscapes. Loss of aspen can be attributed primarily to successional processes that occur in the absence of natural fire regimes and with excessive browsing. Continuation of the current successional trend, which has existed for the past 100–140 years on the Eagle Lake Ranger District, will result in the eventual loss of most aspen stands. The District's extensive inventory and restoration efforts are an attempt to avoid this loss.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## Monitoring Changes in Channel Morphology to Evaluate Management Actions Concerning the Merced River in Yosemite Valley<sup>1</sup>

C. Marie Denn<sup>2</sup>

Stream channel morphology alters in accordance with changes in riverbank and floodplain land use and can measurably respond to land use changes on 4- to 10-year time scales. Yosemite National Park is continuing a long-term channel morphology monitoring program, initiated in 1989, to evaluate effects of development, recreation, restoration, dam removal, and natural disturbance events on the Merced Wild and Scenic River in Yosemite Valley. This monitoring program has revealed effects of development and intensive riverbank restoration on the river and provided better understanding of the 100-year flood of 1997. In the future, this study will show alterations in the river channel structure due to post-flood policy and land use changes.

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## Modeling Ozone Uptake in Ponderosa Pine throughout the Sierra Nevada<sup>1</sup>

Jeanne A. Panek,<sup>2</sup> Laurent Misson,<sup>2</sup> and Allen H. Goldstein<sup>2</sup>

Tropospheric ozone is a pollutant responsible for forest injury worldwide. It is a strong oxidant that invades foliage through stomatal pores and impairs normal physiological function. In the Sierra Nevada, ozone uptake can be unrelated to ozone concentrations. Peak ozone concentrations occur in the late summer, but uptake then is low because of stomatal closure in response to moisture stress. Thus, concentration-based indices of ozone exposure do not accurately reflect the ozone “seen” by plants. To estimate ozone uptake in ponderosa pine (the most ozone-sensitive Sierra Nevadan conifer) throughout the Sierra Nevada, gas exchange/physiology was directly measured at four sites along an ozone gradient for three growing seasons and one winter. From these data, a model was developed and validated. This model was then used to estimate ozone flux (ozone concentration relative to canopy conductance to ozone) across the Sierra Nevada through time. This approach can be used to develop cause-effect relationships between ozone stress and forest injury in pine. The uptake-modeling method is being adopted across Europe to replace concentration-based indices. This is one of the very few studies attempting to model ozone flux to forests in the United States, and it will contribute to improvements in monitoring of Sierra Nevada forest health in response to ozone pollution.

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## Evaporation from Lake Tahoe, California<sup>1</sup>

Gayle L. Dana,<sup>2</sup> James C. Trask,<sup>3</sup> and David McGraw<sup>2</sup>

Accurate measurements of evaporation are important to management of water storage as well as to understanding turnover and nutrient storage in lakes. Evaporation has been a poorly constrained component in past water budget studies of Lake Tahoe, California, and is the last major unknown for effective management of the Truckee River Basin under the Truckee River Operating Agreement (TROA). To obtain evaporation rates from Lake Tahoe, two studies of evaporation were conducted from September 1999 to December 2000. The first study was designed to obtain the best possible and first year-round measurements of evaporation using the eddy correlation technique. The second study was designed to determine the accuracy of evaporation estimates obtained from the historical Tahoe City evaporation pan, which are suspect as a result of progressive shading over time. In this second study, evaporation was measured with a class-A standard evaporation pan placed in a location with minimal shading and wind obstruction at the U.S. Coast Guard (USCG) station a few miles from Tahoe City.

Annual evaporation measured by eddy correlation was 672 millimeters (mm), compared to 674 to 1,099 mm estimated in previous studies. Annual evaporation estimated using meteorological methods (for example, modified Penman) varied sevenfold, indicating that calibration to the eddy correlation measurements would be necessary to use these methods to accurately represent annual evaporation. Pan evaporation measured at the USCG site was 1.5 to 2 times higher than at the Tahoe City site, and evaporation at both sites was higher than that measured with eddy correlation. These results demonstrate that selection of a site-specific pan coefficient is essential to obtaining reliable evaporation estimates.

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## Wildfire Burn Patterns and Riparian Vegetation Response along Two Northern Sierra Nevada Creeks<sup>1</sup>

Leda N. Kobziar<sup>2</sup> and Joe R. McBride<sup>2</sup>

Although the role of fire in forested ecosystems of the Sierra Nevada has been the subject of considerable research, little is known about how fire affects the riparian zones of these forests. This study compares the effects of wildfire on riparian vegetation characteristics along two small creeks in the northern Sierra Nevada mixed conifer forest type of the Plumas National Forest. The behavior and severity of the fire are addressed in relation to the physical characteristics of the two creeks, and the vegetation response patterns are analyzed. Where fire appeared to have burned more quickly through transects on Fourth Water Creek, more of the remaining plants sprouted than did along Third Water Creek. The predominant regeneration mechanisms of the two creeks also differed. More seedlings were found on Fourth Water Creek transects, whereas plant response along Third Water Creek was mostly vegetative. For both creeks, the percent of burned hardwoods that sprouted increased with proximity to the water's edge. The interplay between fire occurrence and proximity to the water table and the influence of these factors on abundance and composition of riparian vegetation are explored. The results can help guide management strategies aimed at restoring resilience to riparian corridors in disturbance-prone ecosystems.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## In-situ Overland Flow Collection System for Sierra Nevada Watersheds<sup>1</sup>

C. Denton,<sup>2</sup> W.W. Miller,<sup>2</sup> D.W. Johnson,<sup>2</sup> P.S.J. Verburg,<sup>3</sup> and G.L. Dana<sup>3</sup>

A versatile intermediate-scale in-situ overland flow collection system of 50 to 100 square meters (m<sup>2</sup>) or more has been developed to capture surface runoff during natural events. This design is readily applied to a wide range of terrain common to natural watershed settings, including areas that receive considerable amounts of winter snowfall. Cumulative runoff from 13 Sierra Nevada study sites over a 7-month period ranged from a low of 3.9 liters (0.08 L m<sup>-2</sup>) to a high of 21.6 L (0.43 L m<sup>-2</sup>) on slopes less than 10 percent in areas of no visible erosion or surface runoff during both snowmelt and summer precipitation. Importantly, this approach may be useful in directly linking nutrient loading from surface runoff to tributary and lake water quality; NH<sub>4</sub><sup>+</sup>-N concentrations as high as 86.2 milligrams per liter (mg L<sup>-1</sup>) and ortho-PO<sub>4</sub> as high as 28.7 mg L<sup>-1</sup> P were found in the surface runoff. Soil solution extracts and snowmelt were greater than 3 and 2.5 orders of magnitude lower, respectively. These findings are highly pertinent to hydrologic and nutrient transport models in the Lake Tahoe basin and likely pertinent to other watersheds having similar topographic, biological, and climatic characteristics.

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## High Natural Rates of Nutrient Loading to a Montane Reservoir (Crowley Lake, California)<sup>1</sup>

D.R. Dawson,<sup>2</sup> K.N. Rose,<sup>2</sup> R. Jellison,<sup>3</sup> and J.M. Melack<sup>4</sup>

Crowley Lake in Mono County, California (with an area of 17 square kilometers [km<sup>2</sup>] and mean depth of 9 meters), lies in the Long Valley caldera and is a valuable aquatic resource. It is the premier trout fishery in the eastern Sierra Nevada and the largest reservoir in the Los Angeles aqueduct system. In summer, large cyanophyte blooms impair recreational uses and water quality. Nutrient inputs were measured via seven tributary streams originating in alpine and subalpine catchments (total area of 985 km<sup>2</sup>) and passing through grazed lands and light urban development. On two of the tributaries, large natural spring systems contain high concentrations of nitrogen (N), phosphorus (P), and arsenic and constitute the major source of stream loading (greater than 90 percent of P). Measured stream inputs of phosphorus are approximately in balance with reservoir exports, in contrast to those of nitrogen for which exports are nearly three times the measured inputs. Thus, nitrogen fixation is a likely additional source of N.

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## Correlating Biological Indicators of Stress with Ecological Disturbance in Sierra Nevada Lakes<sup>1</sup>

J. Scott McClain,<sup>2</sup> Aaron Roberts,<sup>2</sup> Brant Allen,<sup>3</sup> and James T. Oris<sup>4</sup>

Low levels of ecological degradation are difficult to observe but are important in defining alpine lakes that have low resistance to and long recovery from stress. The technique of categorizing ecological health of a lake, as applied in the eastern United States by the U.S. Environmental Protection Agency, was applied to lakes surrounding the Lake Tahoe basin in the Sierra Nevada. Lake chemistry, littoral and riparian zone content, and human recreational activity were recorded for each of 16 lake sites: Angora, Castle, Donner, Eagle, Fallen Leaf, Gold, Jackson Meadows, Marlette, Prosser Creek, Sand Harbor, Stampede, Spaulding, Tahoe City, Tahoe Keys, Twin, and Topaz. In addition, juvenile rainbow trout (n = 25) were exposed for 48 hours at each site (5 subsites around lake perimeter) in cages submerged at 2.5 meters. Five genes were analyzed for mRNA levels in trout gill and liver: CYP1A1, metallothionein, vitellogenin, activin, and multiple xenobiotic resistance (MXR). Gene expression was statistically analyzed with principle component analysis and correlated with the most important ecological parameters of lake stress. Preliminary conclusions show a wide range of disturbance with specific chemical contact at several sites. This study suggests that inputs to lake water (runoff and motorized watercraft) can be monitored with this assessment regime and that vertebrate stress levels can help to characterize local ecological disturbance.

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## Effects of Prescribed Burning on Stream and Riparian Ecosystems<sup>1</sup>

Leah A. Rogers,<sup>2</sup> Vincent H. Resh,<sup>2</sup> and Scott L. Stephens<sup>3</sup>

In areas where wildfire has been suppressed, prescribed burning can be an efficient forest management tool for fuel reduction and ecosystem restoration. However, concerns about the effects of fire on sensitive habitats, such as streams and riparian areas, have limited its use in management. Though wildfires can have long-lasting effects on physical and biological features of streams and riparian areas, little is known about the effects of prescribed fire. In September 2002, an upland and riparian plot will be burned using prescribed fire at the University of California's Blodgett Forest Research Station in the central Sierra Nevada. Changes in water quality, channel morphology, hydrology, aquatic macroinvertebrates, algal biomass, large woody debris, and riparian forest community dynamics will be documented in burned and unburned first-order catchments before and after the prescribed fire (beyond-BACI design). Multiple control and impact sites are being used to compare pre-fire and post-fire results to provide information on: (1) effects of prescribed burning on streams and riparian zones, (2) effects of fuel reduction in riparian zones, and (3) recovery of streams following disturbance. Pre-fire data and results on immediate effects of the riparian/upland prescribed fire of September 2002 are presented.

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## High-Resolution River Chemistry in the Sierra Nevada<sup>1</sup>

David H. Peterson,<sup>2</sup> R.E. Smith,<sup>2</sup> S.W. Hager,<sup>2</sup> M.D. Dettinger, D.R. Cayan, J.S. DiLeo, and N. K. Huber

Linking variations in large-scale atmospheric circulation patterns (climate) to variations in snowmelt discharge and riverine chemistry is a relatively new science. Three important elements of this research are to: (1) establish a hydroclimate monitoring network, (2) monitor riverine chemistry at rates compatible with hydroclimate variables (hourly, daily), and (3) exploit the remarkable synchronism in spring snowmelt discharge variations between watersheds in the Sierra Nevada. The third element simplifies interpretation of multi-watershed variations in river chemistry. This problem is further simplified here by focusing on the variations in water conductivity, a conservative property measuring total dissolved solids (TDS) or salts.

First year (2001) interbasin results from the Merced and Stanislaus rivers are available. Historically, the correlation of daily discharge of these two rivers has been strong ( $r = +0.98$ , from 1951 to 1993). (The Stanislaus River discharge gauge was discontinued in 1993.) During 2001, a measure of discharge, water pressure or elevation, also showed a strong interbasin correlation at the hourly time scale ( $r = +0.96$  for calendar days 1 to 160). Despite this strong correlation in discharge, the conductivity variations in the two rivers were different. During low river flow, in both rivers, the diurnal peaks of conductivity occurred after the diurnal peak in discharge. Following the onset of snowmelt discharge, this pattern remained the same in the Stanislaus River; however, in the Merced River, the conductivity peak shifted, within 5 days of rising discharge, to occur before the discharge peak. Thus, after snowmelt began, the diurnal conductivity cycles in the two rivers were 180 degrees out of phase. A preliminary explanation for this difference is that the rate of dilution of TDS (dissolved salts) is greater in the Merced than in the Stanislaus watershed (above the gauges).

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## Using Ecosystem Types as Predictors of Variation in the Effects of Riparian Zones on Water Quality<sup>1</sup>

Amy G. Merrill<sup>2</sup>

The Sierra Nevada is experiencing increasingly high rates of nitrogen (N) deposition (for example, 15 kilograms per hectare per year). Expected increases in California's population and fossil fuel use indicate that this trend is likely to continue, possibly endangering water quality and aquatic ecosystem health. Riparian zones and other wetlands are known to remove N from ground and surface waters before they enter aquatic systems. However, variation in N-filtering abilities among different riparian zones is poorly quantified, particularly in mountainous landscapes. This study tested the hypothesis that different riparian ecosystem types are associated with different rates of microbial N uptake, retention, and input to ground and surface water. Twenty plots, four each of five ecosystem types, were randomly selected along a tributary to Lake Tahoe. Throughout the snow-free season, N transformations under background and elevated N conditions were measured. Significant differences in denitrification, net mineralization, and net nitrification were found among ecosystem types under background N conditions. Under elevated N conditions, ecosystem type differences in denitrification and ground water N flux were also significant. These results suggest that classification of riparian ecosystem types can be useful in predicting and accurately modeling landscape scale patterns of riparian zone influence on ground and stream water N.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## Automated Hourly Measurements of Concentrations of Nitrate plus Nitrite and Dissolved Silica at Happy Isles Bridge, Yosemite National Park<sup>1</sup>

Stephen W. Hager,<sup>2</sup> Richard E. Smith,<sup>2</sup> and David H. Peterson<sup>2</sup>

Linking variations in climate to variations in river chemistry requires monitoring chemical variations at rates similar to those of hydro-climate variables. Hourly measurements of nitrate plus nitrite (N+N) and dissolved silica (DSi) are now being made in the Merced River at Happy Isles Bridge in Yosemite National Park. The instruments (NAS-2E and AutoLAB; W.S. Envirotech, U.K.) are user-programmable colorimetric analyzers. Stable analytical routines, capable of observing the small hourly variations seen in snowmelt, have been developed. Precision (two standard deviations on the blank) is typically better than 0.1 micromoles per liter for N+N and 0.8 micromoles per liter for DSi. Although the NAS-2E is submersible, deployment of the analyzers on the bank of the river allows more elaborate analytical routines, larger reagent quantities, and renewable (solar) power, while ensuring the lowest possible chance of contamination of the river. Deployments of up to 12 weeks have been made with the N+N analyzer.

Data obtained demonstrate the utility of hourly sampling toward understanding the pathways that snowmelt water goes through on its way to the gauge. Concentrations of N+N undergo regular diel cycles during snowmelt. At the beginning of snowmelt season, concentrations increase as flows do: the "first flush" phenomenon. Later in the year, comparison with hourly conductivity measurements reveals the relative timing of at least two pathways. Rain events following periods of dry weather also have distinct signatures. Concentrations of DSi show a progressive decrease through the spring. Possible explanations include depletion of DSi in soils, changes in source areas, and biological uptake.

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## Magnitude and Interannual Variability of Sediment Production from Forest Roads in the Sierra Nevada<sup>1</sup>

Drew Coe<sup>2</sup> and Lee H. MacDonald<sup>2</sup>

In many forested catchments, roads are the primary source of sediment. However, little is known about sediment production from forest roads in the Sierra Nevada. The objectives of this study were to: (1) measure sediment production and site variables from native surface and rocked roads, respectively, and (2) develop models to predict road surface sediment production. Sediment production rates were measured at the road segment scale by constructing 70 sediment fences and monitoring sediment production rates for 1 to 3 years. The road segments were in the American and Cosumnes river drainages at elevations of 900 to 2,000 meters and included both public and private roads.

For the 1999–2000 wet season, the mean sediment production rate for native surface roads was 7.6 metric tons per hectare per year ( $t\ ha^{-1}\ yr^{-1}$ ), and the range was 0.4 to 33  $t\ ha^{-1}\ yr^{-1}$ . For the 2000–2001 wet season, the same road segments averaged only 1.4  $t\ ha^{-1}\ yr^{-1}$ , and the range of values was correspondingly reduced to 0.03–4.9  $t\ ha^{-1}\ yr^{-1}$ . On average, recently graded road segments produced twice as much sediment as comparable segments that had not been recently regraded. Rocked roads produced only 2 to 4 percent as much sediment as comparable native surface roads. The distribution of sediment production rates is highly skewed because a few road segments generated most of the sediment. Preliminary data from the 2001–2002 wet season indicate that sediment production rates were intermediate to the values from the first and second wet seasons.

The large interannual variability in sediment production rates is probably due to differences in the magnitude and character of precipitation. The more persistent snow cover in 2000–2001 appears to have protected the road surface and reduced sediment production rates per unit of precipitation. Approximately 50 percent of the variability in sediment production rates for ungraded native surface roads can be explained by the product of road surface area and road gradient. The largest sediment production rates were from road segments downslope of areas with impermeable bedrock, and this may be attributed to higher runoff rates and the interception of more subsurface stormflow. Older roads with inadequate drainage produced much more sediment per unit area than roads that follow current specifications. In the absence of rocking or paving, improved drainage and road placement are the best means to reduce erosion from native surface roads.

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# Developing a Spatially Explicit Model to Predict Changes in Runoff and Sediment Yields in the Central Sierra Nevada<sup>1</sup>

Lee H. MacDonald,<sup>2</sup> Sandra E. Litschert,<sup>2</sup> and Drew Coe<sup>2</sup>

A lumped conceptual model is currently being used to assess cumulative watershed effects (CWEs) on national forest lands in California. This model converts the estimated effects of different management activities to Equivalent Roaded Acres (ERAs), sums the ERAs for the watershed of concern, and then compares the area-adjusted ERA value to an empirical threshold of concern. Key limitations to this approach include (1) lack of any spatial considerations (for example, a road near the stream generally has the same ERA as a ridgetop road), (2) absence of different coefficients and recovery rates for changes in runoff as compared to changes in erosion, and (3) limited validation at both the site and watershed scale.

Recent increases in geographic information systems, corporate databases, computing power, and field data are facilitating the development of a spatially explicit, quasi-physically based model to more accurately assess CWEs in the central Sierra Nevada. The goal is to develop a modular set of procedures that allows resource specialists to predict changes in runoff and sediment yields for watersheds ranging in scale from approximately 10 to 100 square kilometers.

In its initial phase, the model will predict catchment-scale changes in runoff and erosion due to forest harvest, roads, and fires. The lack of paired-watershed studies in the Sierra Nevada means that management-induced changes in low flows, annual water yields, and peak flows will be estimated from published values. Background and management-induced erosion rates are being obtained from a combination of literature values and field data collected by the authors from 1999 to 2002. The predicted changes in runoff will simply be summed over the catchment being modeled, whereas the sediment model will have procedures to deliver sediment from the hillslope to the channel network as a function of hillslope gradient and distance from the channel. Sediment will be routed through the stream network as a function of stream gradient, drainage area, and particle size. Users will be able to change the suggested default values for calculating changes in runoff and erosion rates, as well as altering the suggested recovery curves and algorithms for sediment delivery.

The model and user interface will be a stand-alone program in Visual Basic that uses ArcObjects and MapObjects. Standard ArcInfo coverages provide the underlying spatial data. The design criteria are to produce a model that (1) is relatively easy to use, (2) allows users to readily change input values and thereby evaluate the sensitivity of the model output to the assumed values, (3) can be readily expanded to accommodate other land management activities or improved predictive algorithms, and (4) will encourage the collection of additional field data by allowing users to input locally derived values.

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# Geology and Landslides in Latour Demonstration State Forest<sup>1</sup>

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The Department of Conservation's California Geological Survey (CGS) provides technical information about landslides, erosion, sedimentation, and other geologic hazards to agencies making land use decisions in watersheds where proposed activities may affect public safety, water quality, and fish habitat. At the request of the California Department of Forestry and Fire Protection, CGS conducted a study of geologic and geomorphic features related to landsliding for use in the 1994 Latour Demonstration State Forest (Shasta County) Sustained Yield Plan (SYP). The results of the study were portrayed on 1:24,000 scale maps in contiguous parts of the Miller Mountain, Hagaman Gulch, Jacks Backbone, and Manzanita Lake 7.5-minute quadrangles, which include the headwaters of South Cow Creek and Old Cow Creek. Landslide susceptibility categories were also identified. In anticipation of the 10-year update of the SYP, CGS digitized the 1994 maps using an ArcInfo Geographic Information System, with associated data attributes and metadata compiled into an ArcInfo database. Geology and landslide features on the digitized maps will be updated through field surveys, review of existing publications and air photos, and use of selected landslide-related models. Landslide potential will be recalculated so that information on both sets of maps will be consistent with methods currently being used by CGS for mapping landslides on California's north coast.

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## Potential Impacts of Sudden Oak Death in the Sierra Nevada<sup>1</sup>

Doug McCreary<sup>2</sup>

Sudden Oak Death, or SOD, is a new type of mortality that affects oaks in coastal areas. It is caused by a recently named fungus-like pathogen, *Phytophthora ramorum*, that kills trees by causing stem lesions. It has currently been confirmed in 12 coastal counties ranging from Monterey to Humboldt. In addition to oaks, this pathogen also infects about a dozen other plant species that may harbor the pathogen but are not necessarily killed by it. As of this writing (August 2002), this disease has not yet been confirmed in any Sierra Nevada counties; however, there is concern that it could spread to these areas. Several confirmed hosts, including California black oak, big leaf maple, madrone, and manzanita, grow in the Sierra Nevada, and environmental conditions in the mid-elevation foothills are not that different from those in infested coastal regions.

If SOD were to become established in the Sierra Nevada, it could have serious negative impacts, including increased risk of wildfires, adverse effects on wildlife habitat and associated wildlife species, increased potential for erosion and resulting degradation in water quality, and a dramatic alteration in the visual landscape. It is therefore critical that efforts be taken to minimize the risk of spread from coastal areas to the Sierra Nevada.

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## Decline of Sugar Pine in the Sierra Nevada<sup>1</sup>

Phillip J. van Mantgem<sup>2</sup> and Nathan L. Stephenson<sup>2</sup>

Throughout the Sierra Nevada, sugar pine is under attack from an exotic pathogen, white pine blister rust (*Cronartium ribicola*). Although the range and severity of infection are relatively well known, long-term demographic data that document the actual impact of the disease are lacking. Population trends have been estimated based on data collected from observations of 1,668 individual sugar pines over 5 to 15 years at four different sites in Sequoia and Yosemite National Parks. Populations are declining at most sites (lambda range: 1.01 to -0.82), and no site presents unequivocal evidence for population growth or stability as indicated by bootstrapped confidence intervals. Sensitivity analysis demonstrates that population growth rates are most closely tied to large tree survivorship. A retrospective analysis of the data shows, however, that poor recruitment is the primary cause of among-site differences with respect to the rate of population decline. Population change occurs very slowly for most tree species, and stochastic projections of this study's population models suggest that sugar pine will not become locally extinct at any of the study sites within the next 50 years. Nevertheless, local extinctions are likely within a generation, and additional stressors, such as fire, increased pathogen virulence, or climate change, may accelerate the rate of decline.

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## Amphibian Disease Dynamics in a Fragmented Landscape<sup>1</sup>

Cheryl Briggs,<sup>2</sup> Lara Rachowicz,<sup>3</sup> Vance Vredenburg,<sup>3</sup> John Taylor,<sup>3</sup> John Parker,<sup>3</sup> Craig Moritz,<sup>3</sup> Martha Hoopes,<sup>3</sup> Rob Bingham,<sup>3</sup> and Roland Knapp<sup>4</sup>

Impacts of a newly identified chytrid fungal pathogen, *Batrachochytrium dendrobatidis*, on populations of mountain yellow-legged frogs, *Rana muscosa*, are being studied. The chytrid fungus was first described in 1998 but has already been implicated in declines of amphibian populations worldwide. Reports of *R. muscosa* die-offs in the Sierra Nevada associated with the presence of the disease have been accumulating over the past 5 years. Laboratory and field experiments are being conducted to quantify the transmission process and understand effects of the disease on individual tadpoles and frogs. Results indicate that individuals infected as tadpoles die from the disease within days after metamorphosis. Field surveys and resurveys are documenting spread of the disease through the Sierra Nevada and impacts of the disease on *R. muscosa* populations. Information from transmission experiments, field surveys, and detailed studies of frog movement patterns will be used to establish parameters for spatially explicit models of the frog-chytrid relationship. The models will be used to help understand the host-disease interaction and suggest management strategies.

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## Ecology of an Arboreal Forage Lichen in Sierra Nevada Red Fir and Mixed Conifer Forests<sup>1</sup>

Tom Rambo<sup>2</sup>

*Bryoria fremontii* is an arboreal lichen with important ecological linkages in Sierra Nevada forests. It is primary winter forage and nesting material for the northern flying squirrel, which itself serves as important prey for several sensitive species, including the California spotted owl, northern goshawk, marten, and fisher. Little is known about the effects of dispersed versus aggregated live-tree retention on the viability of arboreal lichens, and overall ecological knowledge of lichen epiphytes in these forests is limited. However, lichens are highly susceptible to forest thinning and environmental disturbances, especially those that produce changes in microclimate.

*Bryoria* distribution appears to be highly positively associated with red fir. This ongoing study will quantify the degree of this association, explore its nature, and assess the effect of overstory versus understory thinning treatments on *Bryoria* transplants in conjunction with the Teakettle Ecosystem Experiment. Overstory thinning produces a pattern of dispersed live-tree retention, whereas understory thinning is more apt to leave trees aggregated in groups. Results will provide forest managers with information on which thinning pattern, tree species, and habitat conditions are more favorable for fostering *Bryoria* populations. Conservation of *Bryoria*, in turn, has broad implications for the conservation of sensitive species and biodiversity in Sierra Nevada forests.

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# Meadow Fragmentation in Yosemite National Park as Indicated by Invertebrate Distributions<sup>1</sup>

Jeff G. Holmquist<sup>2</sup> and Jutta Schmidt-Gengenbach<sup>2</sup>

Fragmentation of meadow plant assemblages by trails is relatively apparent, but effects on mobile fauna are more difficult to discern. Disturbance to vegetation may reduce habitat available for fauna to a greater extent than would be suggested by damage to plants, because even narrow gaps can greatly change the ratio of “edge” to “core” habitat in the surviving vegetation. Meadow invertebrate fauna were sampled using transects that ran perpendicular to trails to assess functional fragmentation of the meadow assemblage. A secondary goal was to provide baseline data on this important terrestrial assemblage.

Five low-elevation sites (Yosemite Valley) and five high-elevation sites (Tuolumne Meadows) were sampled over a 2-year period. Each site was sampled during both early (high soil moisture) and late (low moisture) season. At each site, a sample was taken in the trail, in meadow vegetation at the trail edge, and at 2, 5, and 10 meters from the trail. A suction extraction technique was developed for collecting surface-dwelling invertebrates: a Craftsman 320 km/h gasoline vacuum modified with a mesh collecting chamber inserted in the two intake tubes. Before vacuuming, a 0.5-square-meter steel quadrat with a mesh covering was thrown onto a randomly-determined location along the transect and staked into place. The vacuum tube was then inserted through an elasticized hole in the mesh and worked through the vegetation to remove fauna.

The meadow invertebrate assemblage proved to be remarkably diverse, with relatively low dominance of any one form, even at the taxonomic level of order. Mites were the most abundant organisms (Acari, 24 percent of fauna), followed by ants (*Hymenoptera*, 23 percent), beetles (*Coleoptera*, 11 percent), leafhoppers (*Homoptera*, 11 percent), flies (*Diptera*, 10 percent), and substantial numbers of spiders, bristletails, true bugs, grasshoppers, caddisflies, moths, lacewings, and other insects. There were 178.4 arthropods per square meter in the early season versus only 24.4 per square meter in the late season, and low-elevation sites had 2.2 times the overall abundance of high-elevation sites (139 versus 64 animals per square meter).

The effects of trails extended further into the surrounding meadow habitat than would have been predicted on the basis of vegetation alone. Invertebrate assemblages in portions of meadows bordering trails had 24 percent of the abundance of “core” meadow areas across all species. Ants provide a good example of the extension of trail effects into intact meadow vegetation. There was an average of 1.6 ants per square meter in trails, and 5.0, 9.0, and 63.6 ants per square meter in vegetation next to trails, 2 meters from trails, and 5 to 10 meters from trails, respectively. Abundances on the trails were even lower than expected: there was a mean of only 10.2 invertebrates (of all types) per square meter of trail versus 157.5 animals per square meter of core meadow habitat.

Meadows harbor a diverse and sensitive assemblage of invertebrates that is not readily visible. Trails negatively influence higher trophic levels, including both primary (for example, leafhoppers) and secondary (for example, spiders) consumers. Invertebrates are affected over an area that is 20 times greater than that of the removed vegetation; footpaths should be planned with the understanding that ecological “footprints” of trails extend beyond the limits of visible disturbance.

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## Pattern and Scale of Large Tree Distributions in the Sierra Nevada: Implications for Inventory, Monitoring, and Management<sup>1</sup>

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The abundance and distribution of large trees is of primary importance in defining and measuring old forests in the Sierra Nevada. Most data used for old-forest and wildlife-habitat relations analysis and research is from small, sub-acre plots and low sampling intensities. Yet these data are often extrapolated to stand and even landscape scales. The accuracy and precision associated with different sampling intensities were evaluated in computer-simulated and actual old forest stands. Simulations of estimate precision with increasing sample area (0.1 to 25 percent) show that larger sample areas (greater than 5 percent) are needed when large tree densities are low—a common situation in the Sierra Nevada. Monte-Carlo permutations of 100 random selections of typical plots (0.10 to 1.6 acres) in stem-mapped old forest stands indicate that applied sample size areas are insufficient to accurately estimate large tree densities. This is partly due to the patchy distribution of large trees in stands in the Sierra Nevada. The most commonly used data set in the Sierra Nevada is the Forest Inventory and Analysis data, which represents less than 0.2 percent of a sample area. These results suggest that extrapolating small-plot data on large trees to stand or landscape scales may not only be inappropriate, but it also may be highly inaccurate.

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## Fisher Population Monitoring in the Kings River Adaptive Management Area<sup>1</sup>

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Recent surveys have shown that fishers in the southern Sierra Nevada are isolated from other populations in the state by approximately 400 kilometers. Because of this isolation and because these populations occupy the southernmost extent of this species' range, managers are concerned about the conservation of fishers in California. To validate the regional surveys at a local scale, fisher population monitoring in the Kings River Adaptive Management Area is focused on the dynamics of a subpopulation using mark-recapture methods. In order to develop an efficient method for monitoring fisher populations at this scale, two recapture methods are being compared: re-sight of ear-tagged animals with automatically triggered cameras and DNA-based individual identification from hair samples. Preliminary surveys have been successful in identifying recaptured fishers using photo stations. Techniques for genotyping hair samples using microsatellites are being developed.

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## The Importance of Riparian Habitat to Northern Flying Squirrels at the Teakettle Experimental Forest<sup>1</sup>

Marc D. Meyer,<sup>2</sup> Douglas A. Kelt,<sup>2</sup> and Malcolm North<sup>3</sup>

The northern flying squirrel (*Glaucomys sabrinus*) is an important species for forest management in the Sierra Nevada because it is the principal prey of California spotted owls (*Strix occidentalis occidentalis*) and an agent of dispersal for hypogeous ectomycorrhizal fungi. Flying squirrels, hypogeous sporocarps (truffles), and several habitat factors were sampled in 18 separate old-growth forest stands in the southern Sierra Nevada to determine factors associated with flying squirrel abundance. Results demonstrated that creek area and distance were the only habitat factors significantly associated with flying squirrel abundance at the study site. Moreover, greater frequency, richness, and biomass of hypogeous fungi sporocarps were found in riparian areas relative to drier, upland sites. Flying squirrels may be strongly associated with perennial creeks at this study site because truffles have greater abundance and a longer fruiting season along creeks than the ephemeral truffle crop on upland sites. The results underscore the importance of perennial streams and creeks for wildlife in Sierra Nevada forest ecosystems.

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## Research Natural Areas in the Sierra Nevada Bioregion: Contribution to Biodiversity Conservation and Opportunities for Research<sup>1</sup>

Constance Millar<sup>2</sup> and Hugh Safford<sup>3</sup>

The Research Natural Areas (RNA) program is a nationwide Federal network of public lands established to conserve biological diversity, provide baseline ecological information, and encourage scientific research. Areas selected are usually larger than 5,000 acres and exemplify minimally disturbed ecosystems representative of the range of terrestrial vegetation and habitat types administered by Federal land management agencies. The lands are strictly managed for biodiversity and environmental protection, but nonmanipulative research and monitoring are encouraged as primary objectives.

The Pacific Southwest Research Station and Pacific Southwest Region jointly manage the California program. In the Sierra Nevada, 22 RNAs have been established, and 20 more are pending establishment. RNAs range from low-elevation foothill grasslands on the west side and pinyon-juniper woodlands on the east side through the elevational zones to alpine fell-fields. Unpublished ecological surveys, which include detailed species lists, vegetation type maps, soils maps, and land use history exist for most of these areas. Many RNAs have long been sites of intensive research. The Hall RNA, for instance, on the Tioga Crest, was the location for pioneering genecological research by Clausen, Keck, and Hiesey in the 1940s. Current research by Schemske and colleagues continues the historic work at the molecular level.

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## California Spotted Owl Demographics in the Southern Sierra Nevada, 1990-2001<sup>1</sup>

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California spotted owl (*Strix occidentalis occidentalis*) demography has been examined at study areas in the Sierra National Forest (265 square miles) and Sequoia-Kings Canyon National Parks (132 square miles) for 12 consecutive years. The Sierra National Forest study area has been managed for multiple-use including timber harvest, whereas Sequoia-Kings Canyon National Parks has been managed as a National Park with removal of trees limited for decades. Standard spotted-owl study techniques were used to assess survival and reproductive success. The average fecundity for the Sierra National Forest study area for 1990 through 2001 was 0.2652 (se = 0.0690), estimated from an intercept only (means) model. Average fecundity for Sequoia-Kings Canyon National Parks from 1991 through 2001 was 0.2679 (se = 0.0703). On both study areas, fecundity rates varied substantially from year to year, whereas survival rates appeared less variable. Estimated adult apparent survival (F) was higher for Sequoia-Kings Canyon National Parks [F = 0.8774 (se = 0.0149)] than for Sierra National Forest [F = 0.8301 (se = 0.0154)]. The difference in forest management between study areas is only one of many possible explanations for the difference in survival. Further analyses that incorporate measures of vegetation structure and composition may provide insights into factors that may be causing this difference in survival.

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## Willow Flycatcher Meadow Habitat Parameters in the Sierra Nevada Bioregion<sup>1</sup>

Rosemary A. Stefani<sup>2</sup>

Efforts to successfully model suitable habitat for the State endangered willow flycatcher (*Empidonax traillii*) across 11 million acres of the Sierra Nevada bioregion have been limited. Recent habitat selection modeling of this bird species in the north-central Sierra Nevada indicates that it is significantly more likely to be detected at sites with standing water or saturated soils and an abundance of riparian deciduous shrubs. In addition, site size often matters: more than 80 percent of willow flycatcher territories in the Sierra Nevada occur in meadows larger than 8 hectares. However, other features of known willow flycatcher sites in the north-central Sierra, such as dominant plant species, vegetation patch shape, amount and source of water, vary widely. This field study, which commenced in June 2002 and concluded at the end of September 2002, will assess and photo-document biotic, abiotic, and anthropogenic conditions in more than 100 known willow flycatcher sites as well as meadows that meet the general definition of potential willow flycatcher habitat (wet or moist meadows larger than 6 hectares with a riparian deciduous shrub component) in 11 national forests of the bioregion. These data will be used to determine whether there are any significant differences between known and potential site conditions that can be used to identify suitable willow flycatcher habitat model parameters for the bioregion. Summary statistics of condition assessment variables for known and potential willow flycatcher sites will be presented and future work identified.

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## **Predator Abundance and Habitat Relationships in the Central Sierra Nevada<sup>1</sup>**

**Andrew Hatch<sup>2</sup>**

Forest ecosystems of the northern Sierra Nevada, between Lassen and Yosemite National Parks, have been subject to large-scale human alteration and management for hundreds of years. Predators with specific habitat requirements and rare predators, such as the Sierra Nevada red fox, California wolverine, and Pacific fisher, apparently are extirpated from this region. Since 1997, the Central Sierra Environmental Resource Center has placed more than 125 carnivore scent-stations throughout the Stanislaus National Forest. The low statistical power of the scent-station survey did not allow for population trends or estimates to be obtained from the data. The relationship between predator abundance and habitat type and quality does give an indication that large, undisturbed regions of high-quality habitat may be a limiting factor for rare predators within the central Sierra Nevada. Forest management practices that decrease fragmentation and increase forest interior could help provide corridors and habitat patches for the Pacific fisher if it is reintroduced or if as yet undiscovered remnant populations survive in the central Sierra Nevada.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## **Finding Core and Corridor Wildland Areas in the Sierra Nevada and Modoc Plateau Using GIS<sup>1</sup>**

**Evan Girvetz<sup>2</sup> and Fraser Shilling<sup>2</sup>**

The goals of the Wildlands Project are to maintain native species, habitat types, ecological and evolutionary processes, and the adaptive nature of North American ecosystems. To help meet these goals for the Sierra Nevada, the landscape was assessed for its ability to support a wildlands network, using a combination of focal species habitats, unfragmented landscapes, and essential connecting and ecologically critical areas. The ArcView extension program “Ecosystem Management Decision-Support” was used to combine these disparate elements and data sets for the Sierra Nevada, Modoc Plateau, and Cascade bioregions. Each 500-by-500 meter-grid cell of the landscape was scored for its contribution to conservation of biodiversity and “wildlands.” Then, using the annealing function of SITES ArcView extension, these grid cell values were gathered together to create “core areas.” Finally, the “Least Cost Path” extension of ArcView was used to create corridor connection among these core areas. This wildlands network was tested for its ability to represent particular plant communities within the network, the overlap between the network and focal species habitat maps, and the proportion of roadless areas and other areas of interest contained within the wildlands system.

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## Avian Biodiversity in the Sierra Nevada over an Elevational Gradient<sup>1</sup>

Kathryn L. Purcell<sup>2</sup> and Douglas A. Drynan<sup>2</sup>

Conserving all species is essential for sustaining ecosystem patterns and processes, and the appropriate focus for wildlife conservation by the Forest Service is on maintaining native biodiversity. Conservation of biological diversity depends on availability of habitat conditions that sustain healthy populations of coexisting species. A closer look at the habitat needs of individual species will enable prediction of their responses to habitat change resulting from management practices.

Bird census and vegetation data were collected at 18 study sites from 1995 through 2002. The sites were distributed across an elevational gradient and occurred in four forest types: ponderosa pine (1,025 to 1,370 meters), mixed conifer (1,710 to 2,010 meters), true fir (2,170 to 2,350 meters), and lodgepole pine (2,470 to 2,775 meters). Species diversity was highest at the lowest elevation sites and decreased with increasing elevation. Abundance generally followed the same pattern and was highest in ponderosa pine and mixed conifer sites. Annual variability was high and related to weather conditions.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## Snow-tracking American martins in the Lake Tahoe Basin: A Quantitative Method for Supporting Science-Based Management<sup>1</sup>

Mary Cablk<sup>2</sup> and Susan Spaulding<sup>3</sup>

American martens (*Martes americana*) are forest carnivores that are known to occur in the Lake Tahoe Basin. In some cases, martens are found in proximity to recreational areas, including ski resorts, snowmobile routes, and campgrounds. Understanding relationships between martens and anthropogenic activities is critical for managing animal populations and their habitats. To address this issue using quantitative methods, research began in January 2002 at Heavenly Ski Resort as a joint effort between Heavenly Ski Resort, Desert Research Institute, and the USDA Forest Service. Methods that incorporate advanced GPS and GIS tools with snow-tracking have been developed. The method has advantages over telemetry in certain situations but also has its own caveats. Data collected directly from snow-tracking includes information on subnivean access, road and trail use or avoidance, and home range sizes. Snow-tracking data are easily incorporated with other data collected using different methods, such as remote cameras or track plate stations. Other analyses can also be conducted with these data, for example, by incorporating them with spatial habitat characteristics to assess habitat preferences. Snow-tracking data can be used to examine the habits of individual animals or to better understand dynamics at a population or landscape scale.

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## Native Bees in Sierra Nevada High Meadows<sup>1</sup>

Richard G. Hatfield<sup>2</sup>

Montane meadows and wetlands, especially those with emergent vegetation, are some of the most productive wildlife habitats in California. The importance of high-elevation wetlands to biodiversity is nowhere more evident than on the arid eastern slope of the Sierra Nevada.

Native bees are the most important animal pollinators of flowering plants in the Sierra Nevada ecosystem. A two-pronged approach was used to examine whether local or regional factors determined native bee diversity in Sierra Nevada eastern slope meadows. First, the diversity of solitary and native bee populations was examined in wet and dry meadows with differing proportions of willow (*Salix* sp.) habitat. Second, the properties of eastern slope meadows that contribute to bumblebee (*Bombus* sp.) diversity were examined. Meadow characteristics compared included size, presence of grazing, grazing history, floral diversity, and proximity to other wet and dry meadows. As the Forest Service, Bureau of Land Management, The Nature Conservancy, and others are currently developing plans for northern Sierra Nevada meadow restoration, this study will provide useful information that can contribute to the management of these important and diverse habitats.

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## Bird Population Dynamics of Sierra Nevada Meadows<sup>1</sup>

Mark D. Reynolds,<sup>2</sup> Julia I. Smith,<sup>3</sup> and Gretchen LeBuhn<sup>4</sup>

Montane meadows of the Sierra Nevada are some of the most productive and imperiled habitats for breeding and migrating landbirds in western North America. The Nature Conservancy has recently established the Northern Sierra Project with the goal of preserving more than 55,000 acres of unprotected mountain meadow habitats. Understanding natural and human influences on the quality of montane meadow habitats for birds in the Sierra Nevada is critical to measuring the success of conservation actions: preservation, mitigation, and restoration. Livestock grazing is believed to be a primary threat.

Meadows in the northern Sierra Nevada vary in size, shape, elevation, hydrology, vegetation, and current and historical management. To understand effects of meadow condition and trend, including grazing, on bird populations, 50 meadows within the greater northern Sierra Nevada region (100-square-kilometer study area) have been sampled over the past several years using standard monitoring protocols (point counts, mist-netting, and nest searches). Meadows varied substantially in size and habitat heterogeneity. Large meadows generally had higher species richness ( $r^2 = 0.44$ ) and diversity ( $r^2 = 0.23$ ) and lower evenness ( $r^2 = 0.17$ ). Meadows had unique species assemblages with low inter-meadow community similarity (mean Jaccard's index =  $0.32 \pm 0.04$ ). Wet-meadows had significantly greater species richness than dry meadows. Wet meadow-dependent bird species were detected infrequently and were concentrated mostly in the northernmost part of the study area. Species richness decreased slightly with erosion pavement and stream incision effects associated with livestock grazing. Bird population metrics will be used as an index to calibrate habitat restoration and measure conservation success.

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## Floristic Similarity of Meadows among National Forests in California<sup>1</sup>

Dave Weixelman<sup>2</sup>

Meadow sites were studied in order to determine floristic similarity of meadows among national forests in California. During the summers of 1999 through 2001, 456 meadows were sampled across 16 national forests in California as part of the Forest Service's range monitoring program. The overall objective of the program was to establish permanent monitoring plots in meadows for recording meadow condition and trend. At each plot, percent frequency of occurrence for each plant species was recorded using 60 quadrat frames. An agglomerative, hierarchical clustering technique, using Euclidean distance measures, was applied to the data using the statistical package SPSS. For this analysis, 186 plant species were used, with sedges (*Cyperaceae*), rushes (*Juncaceae*), and grasses (*Poaceae*) being the main contributors. Only meadows with a water table of less than 100 centimeters were used in the analysis. Results indicate the presence of four significant geographical regions: (1) Sierra Nevada east side and southern Cascade/Sierra Nevada transition forests, (2) southern Cascade and northwestern California forests, (3) central and southern Sierra Nevada west side forests, and (4) southern forests of the transverse range. These results can be used to draw preliminary floristic boundaries for meadow classification work and provide ecological response units for meadow management.

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## Annual Variation and Geographic Patterns in Acorn Production by California Black Oak<sup>1</sup>

Barrett A. Garrison<sup>2</sup> and Walter D. Koenig<sup>3</sup>

California black oak (*Quercus kelloggii*) is the predominant deciduous tree found in montane hardwood and coniferous forests in the Sierra Nevada. Recent assessments of the natural resources in the Sierra Nevada, including the Sierra Nevada Ecosystem Project and the Forest Service's Conservation Framework, have identified conservation issues with this tree species. Many species of birds and mammals feed on acorns produced by California black oak, and acorn production has considerable temporal and spatial variation that may have ecological implications to wildlife, oak recruitment, and forest attributes. Between 1994 and 2001, acorn production was measured at seven sites in California, including three in the Sierra Nevada and southern Cascades. Acorn production varied among years and locations, but production tended to be greatest for trees in southerly latitudes and western longitudes. Tree age and weather were additional factors influencing acorn production by California black oak.

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## Assessing Patterns of Vegetation Change in the Sierra Nevada Using Remotely Sensed Data<sup>1</sup>

Lisa M. Levien,<sup>2</sup> Sean Parks,<sup>2</sup> Scott Shupe,<sup>2</sup> and JoAnn Fites<sup>3</sup>

As human and natural forces continue to alter the landscape, resource agencies, county planners, and local interest groups find it increasingly important to monitor and assess change. Under the Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement (FEIS), old forest ecosystems are identified as needing urgent attention because they are one of the most altered ecosystems in the Sierra Nevada. Knowing the distribution of old forest ecosystems and patterns of vegetation change over time can provide critical information for planning and management processes and tools. Assessing patterns and levels of vegetation change within these ecosystems provides a tool for understanding the impacts that change agents have on the landscape. Vegetation-change data from the California Land Cover Mapping and Monitoring Program (LCMMP) are used to determine the distribution and patterns of change within the Sierra Nevada bioregion. Multi-temporal Landsat Thematic Mapper (TM) data are used to map changes in vegetation cover over an approximately 20-year span. Other geographic layers, including old forest ecosystems data, are used to assess patterns of change across the Sierra Nevada.

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## A Systematic Approach to Assessing the Biodiversity of Bats in the Sierra Nevada<sup>1</sup>

Patricia N. Manley,<sup>2</sup> Ted Weller,<sup>3</sup> and Michelle McKenzie<sup>4</sup>

Bats play an important role in ecosystem function, as well as provide ecological services of unquantified economic value. The most basic information about distribution, abundance, and habitat association is lacking for many bat species, even as evidence suggests that some species are becoming less common and their populations may be declining. In the Sierra Nevada, 11 species of bats are of concern, and basic information gaps pose a barrier to their conservation. The majority of information about bats in the Sierra Nevada has been derived from surveys at non-random locations and known roosts. However, large-scale inventory and monitoring approaches based on a probabilistic sample have the greatest potential to generate reliable information for many species in a relatively short period of time. A second year of testing a systematic, landscape-scale approach to monitoring bat populations, which combines the use of mist-nets with state-of-the-art acoustic monitoring to survey species, is being completed. An analysis of sampling efficiency to describe site-specific species composition has been conducted. A model-based approach is used to estimate detection probabilities for individual species and species richness. Those probabilities are then used to calculate minimum sample size requirements to detect changes in species distribution and richness.

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## Patterns and Thresholds of Fragmentation in Urbanizing Landscapes<sup>1</sup>

Patricia N. Manley<sup>2</sup> and Dennis D. Murphy<sup>3</sup>

Biological diversity is affected by a wide variety of environmental events and processes, including past evolutionary developments, biogeographic processes, extinctions, as well as ongoing ecological influences. In the Sierra Nevada fragmentation and anthropogenic disturbance are key factors that affect the biological diversity and integrity of forested ecosystems at multiple scales. However, the current understanding of the specific effects of fragmentation at multiple spatial and temporal scales and the interactive effects of anthropogenic disturbances is extremely limited.

In the Lake Tahoe Basin, researchers are studying species distribution, species diversity, and ecological integrity across fragmentation and disturbance gradients at the patch scale and interactive threshold effects of fragmentation at the landscape scale. Measures of biological diversity include the presence, abundance, and reproductive status of species most likely to be most affected by fragmentation and disturbance, including birds, small mammals, invertebrates, and vascular plants. Potential patch-scale effects include loss of native species, lower abundance and reproductive success of those species, presence of exotics, and changes in plant phenology that can affect plant-animal interactions. Potential landscape-scale effects of fragmentation include loss of native species, lower population sizes, and isolation of populations. Patch-scale predictive models will be developed and spatially explicit simulation modeling will be used to evaluate landscape-scale thresholds and predict the effects of potential future fragmentation scenarios.

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## A New Inventory and Monitoring Program in Sierra Nevada National Parks<sup>1</sup>

Linda S. Mutch<sup>2</sup>

The National Park Service has implemented an inventory and monitoring program to improve the quality and accessibility of natural resource information for park managers, Park Service policy makers, and the public. The first phase of the program is a biological inventory with the following goals: (1) to document the occurrence of at least 90 percent of vertebrate and vascular plant species estimated to occur in parks and (2) to describe the distribution and relative abundance of species of special management concern, which include listed species, invasive non-native species and other species of special management interest to parks. The second phase of the program will establish long-term monitoring of key indicators of ecosystem change.

To improve the efficiency of an inventory and monitoring program, the Park Service created networks of parks that are linked by geography and shared natural resource characteristics. The Sierra Nevada Network (SNN) includes Devils Postpile National Monument and Sequoia Kings Canyon, and Yosemite National Parks. The SNN is in the third year of a 5-year biological inventory program. Results of baseline inventories for bats, birds, vascular plants, slender salamanders, and invertebrates are available, as is a summary of data management priorities, upcoming inventories, and planning efforts for long-term monitoring.

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## **Characterizing Fire Threats to Communities: Combining Regional and Project Planning Perspectives<sup>1</sup>**

**Dave Sapsis<sup>2</sup> and William Stewart<sup>2</sup>**

Characterizing the scale of the wildland-urban interface problem and improving site-specific responses to fire threats to communities involve different analytical procedures that often do not work well together. Two scales of analysis, regional and project, are used to characterize fire threats to communities in California. At the regional/statewide scale, a standardized procedure is used to combine fire hazard and modern-era fire occurrence into a composite index of fire threat. Housing-density data from the U.S. Census are used to characterize population densities into urban, interface, rural residential, and wildland housing densities. Density grids are then characterized by their maximal fire threat within a 1.5-mile buffer area. The resulting statewide map shows a combined density by proximal fire-threat class.

For project level analysis, spatial fire-growth modeling is used in conjunction with terrain, ownership, detailed housing information, and expected severe fire weather patterns to explore alternative patterns of landscape fuel treatments required for effective reductions in fire risk to communities. The use of strictly defined buffer distances from ownership boundaries will often not effectively modify fire behavior to reduce risk of house loss. Effective project level implementation requires assessing area-specific hazards and opportunities for mitigations, which invariably require flexibility in land allocations and collaboration across jurisdictions.

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## **Decision Support for Road System Analysis and Modification on the Tahoe National Forest<sup>1</sup>**

**Fraser Shilling<sup>2</sup> and Evan Girvetz<sup>2</sup>**

The USDA Forest Service is required to analyze road systems on each National Forest to assess potential environmental impacts. The authors have developed a novel and inexpensive way to do this using the Ecosystem Management Decision Support (EMDS) program (1999). EMDS integrates a user-developed fuzzy logic knowledge base with a grid-based geographic information system to evaluate the degree of truth for assertions about a road's environmental impact. Using spatial data for natural and human processes in the Tahoe National Forest, the authors evaluated the assertion that “the road has a high potential for damaging the environment.” There was a high level of agreement between the products of this evaluation and ground observations of a Tahoe National Forest transportation engineer, as well as occurrences of road failures. Network analysis showed that, of 8,233 kilometers of road analyzed in the Forest, 3,483 kilometers (42 percent) must be kept in a modified road network to ensure access to 1,573 points of interest in the Forest. The modified network was found to have significantly fewer “cherry stem” roads intruding into patches, an improved area-weighted mean shape index, and larger mean patch sizes, as compared to the original network. This system could be used by public agencies to analyze infrastructure for environmental or other risk.

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## **Influence of Vegetation and Land Use on Central Sierra Nevada Ranchers<sup>1</sup>**

**Adriana Sulak<sup>2</sup> and Lynn Huntsinger<sup>2</sup>**

Central Sierra Nevada ranchers own thousands of foothill woodland acres, grazed as parts of livestock operations that often use National Forest montane lands in summer. In 2000 and 2001, ranchers with and without Forest Service grazing permits were interviewed about their rangeland use. Fifty-two percent of permittees and 14 percent of non-permittees reported that vegetation change was having a highly important impact on their summer ranges. Ranchers stated that a decline in burning and timber harvest has led to lower understory production, thickening brush, and encroachment into meadows. Prescribed burning and brush removal on summer range were more frequently carried out by non-permittees, whereas on National forest lands, riparian fencing was more frequent. Eighty-seven percent of permittees and 54 percent of non-permittees reported that land development was a “more important” or “highly important” influence on the management of their ranches. Dogs were a major problem, but limits to cattle driving, ownership fragmentation, trespassing, complaints, cars crashing into fences, and poisonings were all mentioned as consequences of demographic change. Participants estimated that an average of 7.6 ranches had been sold in their communities over the past 10 years, fewer than two kept in ranching and the rest developed or soon to be.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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## **The California Legacy Project<sup>1</sup>**

**Heather Barnett<sup>2</sup>**

The California Legacy Project aims to help State agencies and conservation partners make better decisions about how to conserve natural resources and working landscapes. The Legacy Project is creating science-based analytical tools to assist State and Federal agencies, local and regional governments, and public and private groups assess resource values and risks and conservation opportunities for large landscape areas in the state’s major bioregions. Such evaluations guide decision makers to more effective and strategic allocations of funds. Initial landscape-level analyses then can be expanded by individual entities to support more specific planning and project identification. The decision-support tools created by the Legacy Project are flexible. They allow a wide range of users to apply their own values in assessing conservation options in addition to helping frame a statewide conservation strategy. The California Legacy Project poster display includes information on the Project’s goals and key steps in the Project’s work plan. It also includes a demonstration of the California Conservation Digital Atlas, a web-based mapping system developed by the Legacy Project. Users of the Conservation Atlas will be able to combine existing information to derive new information, create custom maps, and download data to their own computers.

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## **A Landscape of Change in Sierra Nevada Watersheds<sup>1</sup>**

**Thomas Gaman<sup>2</sup> and Ron Arnett<sup>2</sup>**

The Sierra Nevada of California is undergoing rapid change owing to past mining, logging, grazing, fire suppression, and road-building practices. Coupled with ongoing urbanization, climate change, fire, and resource use, the choices for Sierra Nevada conservation are fewer and more complex. The Sierra Nevada Ecosystem Project (SNEP) provided a rich foundation of scientific information, but provided no direction. Post-SNEP planners are looking at ways to assess and manage change. Today, many citizens, politicians, agencies, and environmental groups are advocating the establishment of a Sierra Nevada Conservancy.

During spring 2002, as part of a broad effort to quantify natural resource issues, East-West Forestry Associates, Inc. used a geographical information system (GIS) to assess impacts of the drivers of change upon Sierra Nevada natural resources. Based on SNEP, California Department of Forestry and Fire Protection, and Fire and Resource Assessment Program (FRAP) data, the 2000 Census, California Department of Finance demographic projections, and a wide variety of other public information, 20 thematic coverages of the Sierra Nevada region were assembled. From these, three primary map sets were created: (1) population pressure, (2) resources at risk, and (3) change in the working landscape. This poster presents these maps, which highlight and quantify current conditions and projected changes throughout the 25 major Sierra Nevada watersheds.

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## **Forest and Range 2002 Assessment: The Changing California, Assessing Resource Sustainability within the Sierra Nevada and across California<sup>1</sup>**

**Chris Zimny<sup>2</sup>**

Policies and strategies that guide use and management of the Sierra Nevada are extensive because there are so many topics of concern. This situation is no different than at the statewide, national, or international level. The California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP) is mandated to periodically assess the status and trends of California's 80 million acres of forest and rangeland resources to provide information for developing and implementing resource policies for the State.

The Web-based assessment has adopted international criteria and indicators for resource sustainability from the Montreal Process as the framework for assessing forest and rangeland resources in California and subregions such as the Sierra Nevada. This framework identifies seven board criteria that are essential to resource sustainability: biological diversity; maintenance of productive capacity; forest health and vitality; soil and water conservation; forest contribution to global carbon cycles; socioeconomic benefits; and legal, institutional, and economic framework for forest conservation and sustainable forest management. Highlighted findings from the assessment focus on the interrelationships of change agents, such as fire, global markets for products, global environmental impacts, and the potential impact of California's growing population on ecosystem and rural socioeconomic conditions.

<sup>1</sup> This abstract summarizes a poster that was presented at the Sierra Nevada Science Symposium, October 7–10, 2002, Kings Beach, California.

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