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Viewing Forests Through a Historical Lens

Eric Knapp

Glen Everest (Pacific Southwest Research Station) shows Linda Johnstone and Maria Benech (Stanislaus National Forest) the growth response of a tree to a 1929 cutting treatment, as revealed by a freshly collected increment core.

Past Records on Fire-Resilient, Biodiverse Stands Could Offer Models for the Future

This year marks the centennial of the Forest Service's nationwide network of 80 experimental forests and ranges, which serve as field laboratories for long-term studies on the science and management of national forests. At the Stanislaus-Tuolumne Experimental Forest in the central Sierra Nevada, a research resurgence is underway thanks to the fortuitous discovery of a trove of useful historical data.

Spanning 1,700 acres of midelevation forest lands within the drainages of the Stanislaus and Tuolumne Rivers, the Stanislaus-Tuolumne Experimental Forest (STEF) was officially established in 1943, although investigative studies in the area actually began in 1922. If the STEF can be said to have a founding father, it was Duncan Dunning, a relentless advocate for designating a section of the Stanislaus National Forest for research. As head of forest management studies for the Pacific Southwest Forest and Range Experiment Station, Dunning made contributions that paved the way toward a more comprehensive understanding of forest dynamics in the region's mixed-conifer belt.

Harry Fowells, chronicler of the STEF's early history, described Dunning as "the keenest observer and best naturalist in the station." Dunning noted that unlogged forest stands at the time were mosaics of clusters of trees, variously aged among groups but relatively even-aged within. These groups, ranging in size from a fraction of an acre to several acres, required different silvicultural prescriptions, he believed. From this concept, Dunning

From Science…

The value of historical forest data: Past studies on forest composition and structure can provide invaluable information on how forests have changed.

Contrasting characters of present-day and historical mixed-conifer forests: Compared to today's stands, early 19th-century forests in the central Sierra were less dense, were much more variable in spatial arrangement and structure, and had greater plant diversity.

Unintended consequences of fire suppression: Fire prevention practices during the past century have inadvertently driven forest complexity to decline and forest biodiversity to diminish.

Resilience to fire: The relative immunity of historical forests to stand-replacing crown fires was due, in part, to a structure that included groups of trees of varying heights and ages, abundant canopy gaps that interrupted crown fuels, and surface fuels kept in check because of frequent fire.

formulated and tested a holistic approach to silviculture that he termed "unit area control," which essentially entailed doing everything necessary for maintaining the desired tree species in these natural groups. In 1928, to address what he viewed as contemporary forestry's failure to properly consider individual trees and their relationships as forest components, Dunning published the first tree-classification system for the Sierra Nevada. Drawing on 15 years of observations on 20,000 marked trees, his seven-point scheme categorized individual ponderosa pines by age class, dominance level, crown development, and vigor. This system, subsequently expanded by other scientists, gave rise to classification tools still in use today.

Other long-term studies overseen by Dunning produced growth-and-yield tables for various conifer species and investigated year-to-year fluctuations in cone crops and the seasonal growth rates of trees. Far ahead of his time, Dunning even conceived of a plan for sustained-yield forestry as an alternative to the "lumbering" techniques then practiced on public and private lands; however, his vision failed to win wide acceptance.

One of Dunning's landmark projects was an experimental plan aimed at tackling a growing concern of the era: as pine-rich forest tracts were logged, mostly fir and cedar—not the valued pines—were the species that grew back. To compare regeneration and growth rates following light, moderate, and heavy selection harvesting, during the 1920s Dunning and his crew set up a dozen 10-acre plots in old-growth stands on the Stanislaus. They painstakingly mapped everything on the landscape: trees, shrubs, downed logs, rocks, and herbaceous plants—even counting stem numbers. Dunning suspected that understory plants were competing with tree seedlings, so species and numbers also were recorded and variations in cover calculated.

Until 1947, crews periodically remeasured postharvest regrowth on some plots. A final report on the project in 1951 concluded that pine regeneration had been disappointingly low, regardless of cutting method. Dunning retired that same year, and as the winds of change blew through the Forest Service, research activity on the Stanislaus dwindled.

Eric Knapp

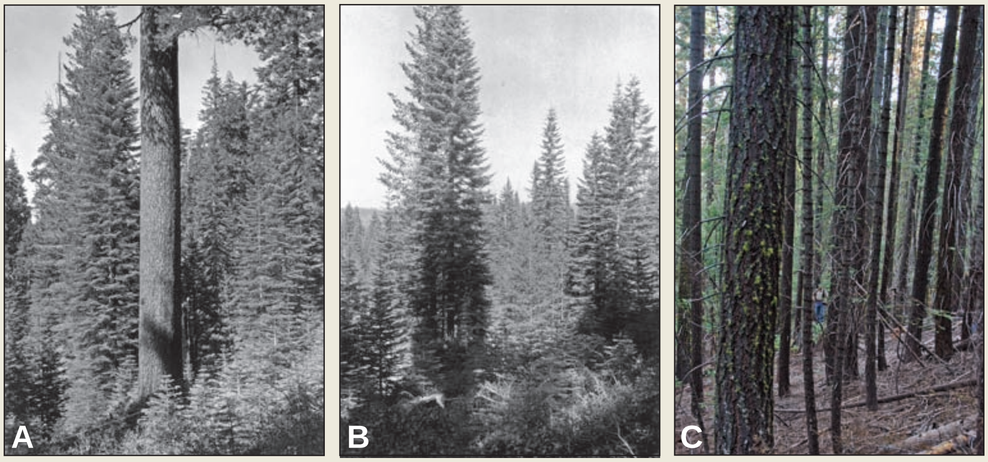
Elias Anoszko remaps historical plots using modern technology—a laser range finder and a geographic positioning system unit.

Then in 2005, Eric Knapp, a relatively new ecologist at the PSW Research Station charged with managing the STEF site, came across Dunning's plot maps squirreled away in a Redding laboratory cabinet. When Knapp made an exploratory trip to the STEF and found tagged trees that matched up with ones on the 80-plus-year-old maps, he recognized an extraordinary opportunity to launch a new chapter of research designed to address compelling questions on today's forests.

Knapp discovered that three of Dunning's original plots—one representing each level of harvesting in 1929—fell within the STEF boundaries, where they had remained undisturbed since the logging. Armed with historical preharvest data and photos, Knapp began an assessment of changes in the forest by remapping the plots in detail.

Comparing the results with the historical data revealed that a sweeping transformation has occurred. The number of trees exceeding 4 inches in diameter has more than doubled. Gaps averaging roughly a quarter-acre in size, once common, have mostly filled in, and so has the forest canopy. However, on average, the fraction of total basal area occupied by sugar and ponderosa pines has dropped from 36 to 20 percent in the stands, while firs and incense cedars have flourished.

Alterations in the understory are equally dramatic. Shrub cover is almost nonexistent, having plummeted from about 30 percent prior to logging to less than 3 percent today, and species important for wildlife browse, such as *Ceanothus* and *Arctostaphylos*, have all but vanished. Similarly, stem numbers for herbaceous species have declined by almost



Three photos from the same location: (a) the uncut stand in May 1929, with a 74-inch sugar pine surrounded by young white firs; (b) October 1929, after logging by the light-cutting method, in which just the largest pines were removed; and (c) in 2007 (in this photo, note the person standing on what remains of the tree stump, and the lack of understory vegetation compared with 1929 conditions).

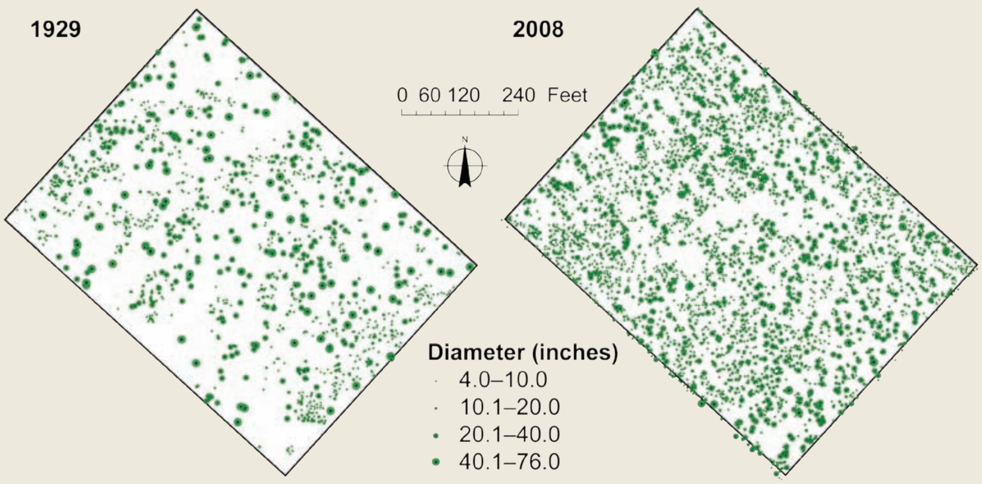


Diagram of an entire 10-acre plot prior to logging in 1929, and in 2008, after 79 years of recovery from logging by the intermediate cutting treatment, along with fire suppression. Note the increasing stand density and reduction in spatial heterogeneity over time.

A 1-acre area of the forest in 1929 before logging, and the same acre in 2008, 79 years after logging with the intermediate cutting system.

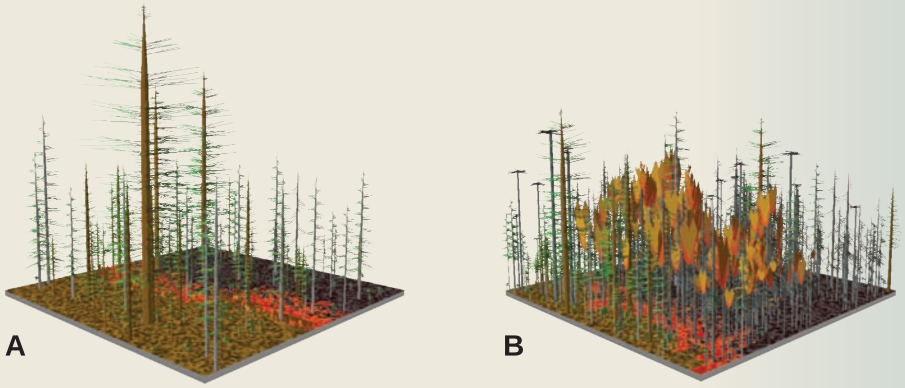
80 percent in the lightly and moderately logged plots—although losses were less in the heavily cut stands, possibly because it took longer for the light-restricting canopy to fill in, Knapp says. As a whole, the remaining understory plant community has shifted to primarily shade-loving plants.

Before versus after: fire, no fire

Coming up with a probable driver for the changes wasn't difficult. Fire scars on tree stumps nearby show the last major fire happened in 1889, but prior to that, blazes swept through the forest about every 5 to 10 years. (Even before suppression became official state policy around 1910, Anglo-European settlers were displacing Native Americans, who routinely modified landscapes with fire.) "Periodic fire favors disturbance-adapted species such as pines and oaks," Knapp explains. "But suppression initiated a different trajectory of forest succession, creating what we currently see in many California forests: dense stands with minimal understory and an abundance of 'ladder' fuels that can promote high-severity crown fires." Indeed, computer model simulations based on the historical versus the contemporary data predict that under typical late-summer conditions, the 1929 stands would experience a surface fire with minimal tree mortality, whereas today's stands would suffer a crown fire with substantial mortality.

These findings support the idea that the relative resilience of presuppression forests to severe fires was linked at least in part to their structure—what Dunning alluded to as the relationships among trees as forest components. The historical maps reveal considerable variability in the ages, heights, and spacing of trees. Likewise, the writings of early forest researchers report that stands on the Sierra's western slope were rarely uniformly dense, but contained clusters of mature trees, numerous gaps, and areas of relatively open canopy that allowed light to nurture more fire-resistant tree species and a diversified understory.

The diminishment of the understory over time has other implications for today's mixed-conifer forests, where issues of biodiversity, protection and recovery of rare species, and ecosystem management are also important concerns. Denizens of the forest,



Expected fire behavior in (A) the 1929 stand prior to logging, and (B) in stands as they look today.

…to Management

Historical records can be invaluable sources of information for developing modern-day targets for restoring forest complexity and enhancing resilience in the face of future environmental challenges such as climate change.

Using variable thinning practices to achieve a more complex forest structure could potentially lead to a more desirable balance between tree species, greater fire resilience, and higher levels of biodiversity in today's mixed-conifer stands.

Experimental forests offer the opportunity for research station scientists and national forest staff to collaborate on projects that address on-the-ground challenges in forest management.

from birds and mammals to invertebrates and amphibians, require a wide spectrum of habitats, so it is reasonable to expect that a more heterogeneous forest will support more wildlife species.

Fire suppression clearly has favored some species over others, says Peter Stine, Program Manager for the PSW Research Station's Sierra Nevada Research Center. For example, surveys show that birds such as the hermit warbler, which prefer closed-canopy forests, are increasing in number, while olive-sided flycatchers and other songbirds adapted to forest openings and edges, are in decline. A preponderance of dense, closed-canopy forest limits the diversity of vegetation types and thus the wildlife community, including the small mammals and songbirds that form the prey base for owls and other predators. On the other hand, truffles that flying squirrels and other species feed on do well in the excess duff and litter that has accumulated with forest densification and fire suppression.

All of this suggests to Knapp that the common practice of removing the small trees and evenly thinning larger trees to create space between the crowns, which can lead to a relatively homogeneous stand, may not be the optimum long-term strategy for reducing fire hazard—despite its short-term effectiveness—or for managing for biodiversity.

Innovative research and a new partnership

In collaboration with staff from the Stanislaus National Forest's Summit District (home to the STEF) and other researchers, Knapp has devised a blueprint for a broad study that would be virtually impossible to conduct outside of an experimental forest. The multiyear project will develop and implement variable thinning prescriptions—based on the Dunning data—in an attempt to achieve a spatial structure similar to the historical forest. The plan also includes carrying out controlled burns in half of the treated plots to better understand the interaction between thinning and fire, and periodically monitoring changes in plant and wildlife communities.

Summit District Ranger Karen Caldwell enthusiastically welcomes the new research. "Forest managers struggle with the question of how to return to a more diverse ecosystem; however, we are very constrained by directives and guidelines to use thinning methods that address the fuels problem but result in a forest without much plant diversity." Her staff has weighed in on management needs, as well as the research plan and will conduct an environmental assessment for the project. Local industry and environmental representatives also participated in these discussions, she adds.

Maria Benech, Summit District Resource Manager, says that Knapp's initial findings already have provided valuable information. The fact that tree numbers have, on average, roughly doubled to more than 300 trees per acre over the last 80 years suggests that district stands exceed optimal densities. And, the revelation that fire events occurred at about 10-year intervals overturns the previous notion of 30- to 40-year events, Benech says. One of the biggest management questions she hopes the new studies will help resolve is how to maintain the majestic sugar pine, which reach peak Sierra concentrations on the district but are seriously threatened by white-pine blister rust.

The project stands to become a model on several fronts: forest ecosystem management, collaboration between national forest staff and station researchers, and reinvigoration of an experimental forest that has been underutilized for decades. "Having an 80-year data set is a dream for most people," Knapp muses. One might guess that Duncan Dunning would be glad to know it landed in Knapp's hands. ■

Eric Knapp

PSW employee Casara Adkins using a chainsaw-mounted increment corer to measure the growth of a sugar pine in response to the 1929 cutting treatment.

Elias Anoszko

Eric Knapp.

Scientist Profile

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Numerous backpacking, skiing, and mountaineering trips in the Sierra Nevada instilled in Eric Knapp a deep sense of awe of this mountain range, and an interest in its management. He received an M.S. and a Ph.D. at the University of California-Davis, specializing in agronomy and plant breeding, later taking on more ecologically oriented research as a postdoctoral researcher, also at UC Davis. In 2004, after a 4-year stint with the U.S. Geological Survey, in which he managed a research program in Sequoia National Park aimed at understanding the ecological effects of different seasons of prescribed burning, he joined the PSW Research Station's Silvicultural Laboratory. Knapp's current research focus is on fire ecology, forest ecology, and fuels management, with a particular interest in using historical insights about forest structure and disturbance regimes to better understand issues of current management concern. Other projects, in addition to his work on the STEF, include studies of fire effects on plants with variables such as burning season; understanding the role of topography, fuels, and weather in generating patterns of fire severity in different landscapes; and fire behavior in nonstandard fuel beds. Knapp also serves as an adjunct faculty member in the Department of Forestry and Wildland Resources at Humboldt State University, where he helps guide the work of graduate students conducting research on joint Forest Service projects. ■

A Conversation With Eric Knapp

Q ***How can historical data such as Dunning's help in setting and working on goals for forest restoration?***

In order to restore fire resilience and biodiversity, it is helpful to have a model for what such a forest looks like. Prior to uncovering these historical data, very little quantitative information was available about the understory of forests before they were first logged. More is known about changes to the forest overstory from contemporary studies that have reconstructed stands based on the location and size of stumps. However, our data show exactly what was there and aren't subject to the biases of reconstruction; i.e., some species decompose more rapidly than others—thus, old fir stumps are less likely to be recorded than pine. Small-diameter stumps are also generally long gone. All this could give the impression that forests were primarily composed of large, widely spaced pine trees. The reality, as these historical data show, is far more complex.

Q ***Objectives on the national forests for fuels management and wildlife habitat management have often seemed to conflict. How might understanding the forests of the past aid in bridging this divide?***

From our fire-history studies, we know that the historical stands were resilient to frequent fire. Many of the wildlife species in trouble today presumably found these stands to be suitable habitat. The diversity in structures, from dense groups of fir trees with overlapping crowns to areas with widely spaced large pines—or even treeless gaps—provided a great diversity of habitats. It also maintained enough discontinuity in surface and crown fuels that wildfires were rarely severe enough to wipe out stands. I don't believe it is possible to re-create exactly what existed at one point in historical time, nor should this be our goal. But understanding the variability in structures and spatial scale of transitions gives us ideas about how we might facilitate the creation of stands that meet fuel management and wildlife habitat needs simultaneously.

Q ***What outcomes do you hope to achieve in terms of scientific results and improved forest management in our changing climate?***

I'm hoping that the historical data—both the raw numbers and stand maps—will help instill in managers and the public a better understanding of how highly altered forests are today—compared to what they once were—and encourage managers to consider how we might work toward greater complexity in today's forests. Complexity could be viewed as a hedge against a changing climate. We don't know exactly what the future will hold, and managing for a diversity of densities, structures, and species will surely increase the probability that at least some parts of our forests will prove resilient to these changes. If we see benefits from more variable thinning with the new study, I think the prescriptions—or at least the underlying rationale for them—could become a powerful tool for meeting the objectives of ecosystem management.

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What's Next

Eric Knapp, wildlife biologist Pat Manley, and ecologist Malcolm North, all of the PSW Research Station, initiated pretreatment data collection for their variable-density thinning study on the STEF during the summer of 2009. Their objectives are to

- Investigate whether a thinning plan modeled after historical stands and designed to produce highly uneven tree density is more beneficial to wildlife and understory plant species than thinning that yields more evenly spaced trees,
- Determine how altering the degree of variability in canopy cover (through thinning) affects the spatial pattern of tree regeneration and the formation of understory "ladder" fuels, and
- Evaluate the benefits of controlling the amount of light on the forest floor (by thinning) versus providing a bare, mineral "seed-friendly" surface (by burning) for the natural regeneration of species such as sugar pine.

Over the course of the project, the scientists will collect data on a range of environmental conditions and outcomes, including the species, abundances, and habitat use of songbirds and small mammals and the establishment, survival, and growth of tree seedlings and understory plants following thinning and burning treatments. ■

Writer's Profile: Noreen Parks has been writing about science and the environment for nearly 20 years, frequently covering topics related to forests and their ecology. A graduate of the science communication program at the University of California-Santa Cruz, her work has appeared in a wide range of print, online, and educational publications. As a former resident of California, she retains fond memories of hiking and skiing in Sierra country—including the Stanislaus Forest—and an indelible imprint of the scent of midelevation pines. Following a 15-year sojourn in Hawaii, she now lives in Port Townsend, Washington, on the doorstep to the Olympic Peninsula.

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For Further Reading

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Web Resources

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