CALIFORNIA FIRE SCIENCE CONSORTIUM

JOINT FIRE SCIENCE PROGRAM

Research Brief for Resource Managers

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What is forest resilience and how do we measure it?

North, Malcolm P., Ryan E. Tompkins, Alexis A. Bernal, Brandon M. Collins, Scott L. Stephens, and Robert A. York. "Operational resilience in western US frequent-fire forests." Forest Ecology and Management 507 (2022): 120004. https://doi.org/10.1016/j.foreco.2021.120004

In dry frequent-fire forests of the western US, forest restoration goals are often focused on promoting resilience to disturbances such as wildfires, insects, drought, and climate change; however, these concepts are often discussed in broad, qualitative terms. Clear definitions and quantified metrics and thresholds are important for determining management objectives and evaluating the effectiveness of proposed treatments in meeting restoration goals to promote forest resilience.

Defining resilience requires specifying the forest ecological type. This study focuses on dry Sierra Nevada mixed-conifer forests that historically had frequent, low to mixed severity fire regimes. In these forests large, long-lived conifers served as the “backbone” of ecosystem structure and function providing wildlife habitat, secure carbon storage, and diverse microclimates.

Resistance is a measure of persistence when exposed to a particular stress, such as high intensity fire. This measure is often the primary goal of fuels reduction treatments. Resilience includes resistance mechanisms but is much broader in terms of adaptability to a variety of stressors (e.g. fire, insects, pathogens, and drought) over time. Tree vigor is fundamental to the growth, adaptability, and development of large trees. These large trees sustain the structure, composition, and function of long-lived forest communities at the landscape level. Historical conditions, which are used to understand a range of natural variability, are often used to characterize stand structures that were more resilient to a suite of stressors.

Management Implications

- Quantified metrics and thresholds are needed to define how forest management meets resilience objectives.
- Relative stand density index (SDI) provides a useful measure of tree growth, vigor, and competition which is a key foundation of resilience.
- Relative SDI of historic stands show forests with large fire-tolerant trees had extremely low densities where inter-tree competition was very low or absent.
- Current fuels reduction treatments still maintain high levels of competition.
- Creating stands free of competition requires a fundamental rethinking of how we manage frequent-fire forests for resilience.

Stand density index (SDI) has long been used by forest managers to describe the well-established relationship between tree size and density. Relative SDI compares SDI to a forest type’s maximum SDI (i.e. carrying capacity), which forest ecologists have used to define thresholds of competition within forested stands:

- 25% of maximum SDI = onset of competition
- 35% of maximum SDI = lower limit of full site occupancy
- ≥60% of maximum SDI = zone of imminent mortality driven by density dependent mortality

This study used relative SDI data to compare historic forests to contemporary forests. The study found that historical forests were far less dense and had greater proportions of larger trees (Figure 1). Contemporary forests densities were on average 6-7 times denser in terms of tree stocking and, consequently, average tree size was reduced by 50%.

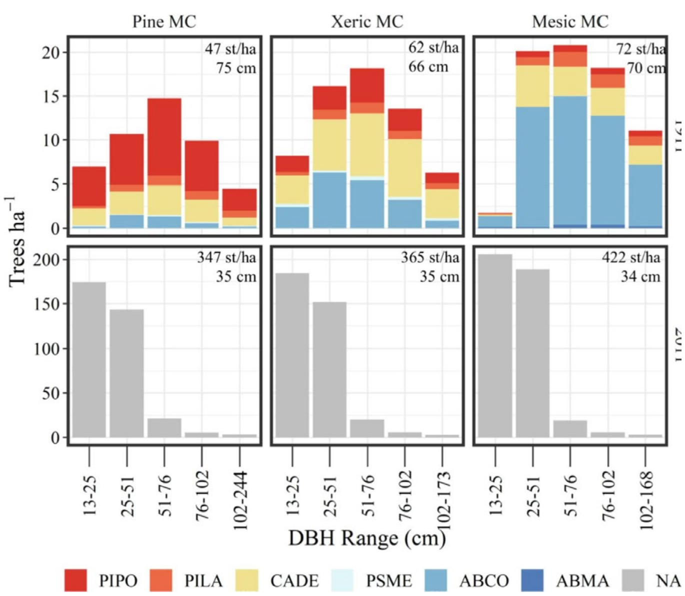

Figure 1. Diameter distributions comparing historic (1911) and contemporary (2011) forest conditions by forest type: Pine Mixed Conifer, Xeric Mixed Conifer, and Mesic Mixed Conifer. Historic forest average stocking ranged from 19-29 trees per acre with average tree sizes between 25-30 inches in diameter. Average stocking in contemporary forests ranged from 140 -171 trees per acre with average tree sizes between 13-14 inches diameter.

All forest types in the historic data set had average relative SDI's indicative of very low competitive environments. Approximate 73-85% of the stands had densities that were below the onset of competition (white zone in Figure 2). In contrast, nearly all contemporary stands had relative SDIs (82-95%) in the zones of full competition or imminent mortality where density dependent competition drives tree mortality.

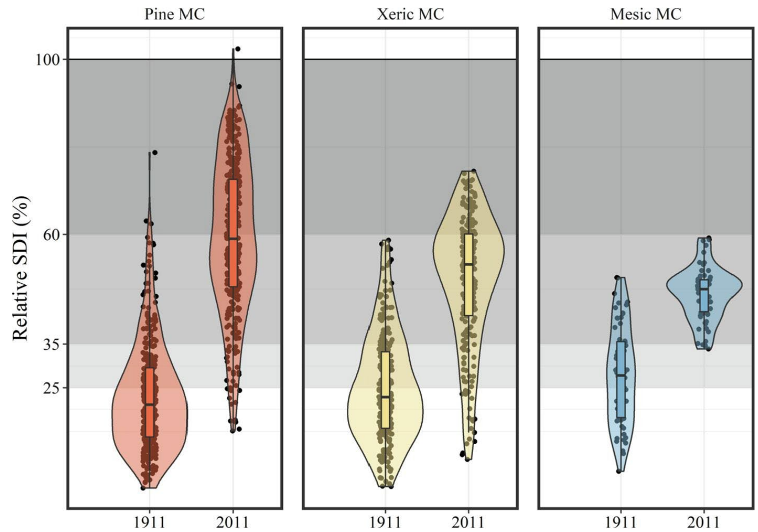

Figure 2. 'Violin' plots comparing relative SDI for historic (1911) and contemporary (2011) forests by forest type. Historic forest densities were far lower and as a result, trees did not have much competition. Contemporary stands have higher densities which maintain inter-tree competition, reduce vigor and growth, and drive density dependent tree mortality.

The much greater relative SDIs in contemporary forests create highly competitive inter-tree environments where growth, vigor, and development of large trees is diminished. Moreover, these data indicate the "habitat requirements" that favor growth, development, and persistence of large fire and drought tolerant trees are best characterized by very open conditions where competition is characterized as absent (<25% of maximum) or very low (25-34% of maximum.

Current management practices focus on retaining higher minimum levels of density, stocking, or canopy cover to meet "desired" conditions result in much higher levels of tree competition. Managing forests to minimize competition would require a fundamental shift in perspective where *contemporary minimum* stocking levels should more appropriately represent *maximum* stocking levels. As a result, far greater proportions of forested landscapes would need be treated for fuels and density reduction – with far greater intensity, to meet forest resilience and restoration objectives.

Suggested Reading:

Long, James N., and John D. Shaw. "A density management diagram for even-aged Sierra Nevada mixed-conifer stands." Western Journal of Applied Forestry 27, no. 4 (2012): 187-195.