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RESTORING RESILIENCY AND SUSTAINABILITY OF FREQUENT-FIRE FORESTS IN THE SOUTHWESTERN U.S.: A SCIENCE-BASED FRAMEWORK

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ABSTRACT

Ponderosa pine and dry mixed-conifer forests in the Southwest United States have become increasingly susceptible to an uncharacteristic severity of wildfires, reduced biodiversity, and impaired ecosystem function. We present a management framework organized around the following key elements to help restore the resiliency and sustainability of these frequent-fire forests: (1) species composition, (2) groups of trees, (3) scattered individual trees, (4) grass-forb-shrub interspaces, (5) snags, logs, and woody debris, and (6) the arrangement of these elements in space and time. Our framework and management recommendations incorporate the natural spatial heterogeneity in composition and structure that historically occurred in these forests. The framework is based on a science synthesis of reference conditions, forest ecology, and lessons learned during implementation of the restoration framework.

Key words: Ecosystem function, forest structure, science application, species composition, spatial distribution.

EXECUTIVE SUMMARY

Some forest types in the Southwestern United States have become increasingly susceptible to an uncharacteristic severity of wildfires, insect and disease episodes, altered plant and animal demographics, reduced biodiversity, impaired ecosystem function and resilience, and reduced ecosystem services. These increased susceptibilities are most evident in forests that historically experienced frequent, low severity fire, primarily ponderosa pine and dry mixed-conifer forests, largely resulting from unregulated livestock grazing and logging around the turn of the 20th century, early fire suppression policy, and other human activities such as development of transportation infrastructure. Associated compositional and structural changes in these forests resulting from these activities include increased tree densities, reduced spatial and structural heterogeneity, decline of grass-forb-shrub communities, and associated losses of habitats and biodiversity.

We present a management framework for restoring the resiliency and sustainability of frequent-fire forests as well the benefits of implementing the framework, including improved ecosystem services such as wood products, clean air and water, and recreation. Our framework is based on a synthesis of the science describing the ecology of these forests in the Southwest (Arizona, New Mexico, southwest Colorado). Key elements of the restoration framework for frequent-fire forests are (1) species composition (tree and understory vegetation), (2) groups of trees, (3) scattered individual trees, (4) grass-forb-shrub interspaces, (5) snags, logs, and woody debris, and (6) the arrangement of these elements in space and time. Our framework is a vision for increasing the resiliency and sustainability of frequent-fire forest ecosystems by restoring the composition, structure, biodiversity, food webs, and the spatio-temporal interrelationship between patterns and processes (e.g., the feedback relationship between structure and fire) in these forests.

Our framework is informed by forest ecology, including reference conditions, natural range of variability, forest silvics, and lessons learned during implementation of the restoration framework. The framework emphasizes ecosystem composition, structure (tree age, size, density), tree spatial patterns, productivity, and function. Additionally, the framework incorporates the natural spatial heterogeneity in composition and structure that historically occurred in these forests and presents management recommendations for restoring this heterogeneity. Sources of spatial heterogeneity are differences in soil, elevation, slope, aspect, and climate, and manifests as differences in tree density, tree establishment patterns and degree of aggregation, and numbers and dispersion of snags and logs. Such heterogeneity is evidenced by within- and among-stand reference conditions that, when summed, comprised the natural range of variability of a forest. The natural range of variability is a “best” estimate of a functioning and resilient system because it reflects the evolutionary ecology of these forests and is thereby a powerful tool for establishing a science basis for restoring the composition, structure, and function of forests.

Studies of historical conditions in ponderosa pine showed that trees typically occurred in groups of 2 to 72 trees that occupied between 0.003 and 0.72 acres each, and with as many as 67 tree groups per acre (10.7-124 trees/acre, 22.1 to 89.3 square feet of basal area per acre). Tree groups were separated by openings of variable sizes and shapes that contained grass-forb-shrub communities and scattered individual trees. The degree of "openness" (the proportion of area not covered by tree crowns, estimated as the inverse of reported canopy cover) ranged from 52-90 percent open, with most studies showing between 78-83 percent openness. In areas exhibiting strong tree aggregation, openness was typically higher (79-90 percent), but on sites exhibiting less tree aggregation, openness may have been lower depending on the arrangement of trees and crown width. Studies report means ranging from 1 to 10 snags and 2 to 20 logs per acre for southwestern ponderosa pine reference condition. These reported densities indicate that the distribution and abundance of snags and logs varied with site and likely coincided with the type, severity, and scale of historical disturbance. Reference conditions in dry mixed-conifer forests were structurally similar to ponderosa pine with respect to the spatial aggregation of trees into groups within an open grass-forb-shrub community. Mean tree densities and basal areas showed a slight increase over ponderosa pine at the fine scale (<120 acres). Reference conditions in Southwest dry mixed-conifer ranged between 20.9 to 99.4 trees per acre (39.6 to 124 square feet of basal area per acre). In areas with fine-scale aggregation, openness in dry mixed-conifer ranged from 78-87 percent. Snag and log abundance appeared to be similar to those in ponderosa pine, but occur at slightly greater abundance. While the historical amount of these structural elements in dry mixed-conifer has received little attention, it is generally accepted that more productive dry mixed-conifer sites may have had higher fuel loads than ponderosa pine sites while still supporting a frequent low-severity fire regime.

Management recommendations presented in this framework encourage managers to recognize the natural spatial and temporal heterogeneity in these forests and to design treatments using local site conditions (i.e., evidence of historical composition and structure such as individual and groups of old trees, snags, logs, stumps) as guides for restoring the resilience and sustainability of these forests. The desired uneven-aged forests comprises an interspersed mosaic of tree groups differing in structural and successional stages that shifts over time, a spatial and temporal pattern that provides and sustains plant and animal habitat adjacency, local biodiversity, and food webs. Our framework recognizes the importance of the types, frequencies, and severities of natural disturbances in shaping the composition and structure of frequent-fire forests, and recommends that fire, perhaps the most influential of historical disturbances in these forests, play a prominent role along with mechanical treatments (e.g., group and single tree selection) in the restoration of the resiliency and sustainability of these forests. While it may not always be feasible to reproduce structural reference conditions, our framework provides an approach developing restoration targets and evaluating treatment outcomes that reflect the historical relationship between pattern and process.

Here we describe a framework for restoring the resiliency and sustainability of frequent-fire forests and present fine-, mid-, and landscape-scale principles and concepts, as well as the science supporting the restored conditions identified in the framework. Our intent is to provide a review of the applicable science on how managers can treat forests to restore ecosystem processes, plant and animal habitats, biodiversity, and sustain ecosystem services.

AUTHORS

Richard T. Reynolds is Research Wildlife Biologist with the U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado. He has investigated the relationship between the composition and structure of habitats and the demographic performance of apex avian predators in forested ecosystems for over 30 years. His recent research focuses on individual and population demographics of northern goshawks and their bird and mammal prey populations in ponderosa pine and mixed-conifer forests on the Kaibab Plateau, Arizona. His research produced management recommendations that restore the native biodiversity, food webs, and goshawk habitat in ponderosa pine and mixed conifer forests.

Andrew J. Sánchez Meador is an Assistant Professor of Biostatistics and Quantitative Ecology in the School of Forestry and the Program Director of Biometrics and Forest Management with the Ecological Restoration Institute at Northern Arizona University in Flagstaff, Arizona. Andrew's most recent research focused on: 1) developing reconstruction and simulation models to characterize fine-scale spatial patterns and reference conditions in ponderosa pine forests of the southwestern U.S.; 2) sampling, describing, and modeling individual tree and forest biomass; and 3) developing spatially-explicit, neighborhood-scale models of forest dynamics. He received his B.S. and M.S. degrees in Forestry from Mississippi State University; and his Ph.D. in Forest Science from Northern Arizona University.

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Andrew D. Graves is Regional Forest Entomologist with the U.S. Forest Service, Forest Health, New Mexico Zone, Southwestern Region in Albuquerque, New Mexico. He has worked in the forests of the upper Midwest, Alaska, and California primarily focusing on bark beetles in these systems. He has worked in the region as an entomologist since 2010. His responsibilities include providing expertise for the Forest Health, Prevention and Suppression Program, providing hazard tree training, and assisting public land managers with forest insect detection, identification, and disturbance mitigation. He received his B.S. degree in Forest Management in 2001 and his Ph.D. in Forest Entomology in 2007 from the University of Minnesota.