United States
Department
of Agriculture

Forest Service

Rocky Mountain
Research Station

Research Note
RMRS-RN-34

April 2008

Fire Effects on Gambel Oak in Southwestern Ponderosa Pine-Oak Forests

Scott R. Abella and Peter Z. Fulé

Abstract—Gambel oak (*Quercus gambelii*) is ecologically and aesthetically valuable in southwestern ponderosa pine (*Pinus ponderosa*) forests. Fire effects on Gambel oak are important because fire may be used in pine-oak forests to manage oak directly or to accomplish other management objectives. We used published literature to: (1) ascertain historical fire regimes in pine-oak forests, (2) discern prescribed burning effects on Gambel oak survival and diameter growth, and (3) provide suggestions for using fire to manage oak. Frequent fire is part of Gambel oak's historical environment, as historical fire return intervals often averaged less than 10 years in pine-oak forests. More than 66 percent of oaks greater than 6 inches (15 cm) in diameter were alive at least 5 years after two contemporary prescribed fires, whereas survival was low (<20 percent) for small oaks less than 2 inches (5 cm) in diameter. Top-killed oaks resprout prolifically, suggesting that fire can maintain shrub-sprout forms of oak constituting browse and cover for some wildlife species. Unlike mechanically thinning competing trees, burning has not been found to increase oak diameter growth. We conclude that fire can be used to manage Gambel oak densities and growth forms, and that large oaks can be maintained during low-intensity burning. Several tactics may enhance survival of large oaks during prescribed fire: keeping pine slash away from oak boles, avoiding lighting near oaks or reducing fire intensity near oaks, and raking fuels away from oak boles.

Introduction

Gambel oak (*Quercus gambelii*) occurs as an understory or mid-story tree in otherwise pure southwestern ponderosa pine (*Pinus ponderosa*) forests. This deciduous oak has high ecological and aesthetic value (Harper and others 1985). Large oaks are particularly valuable to some wildlife species and can live for more than 400 years (Swetnam and Brown 1992). Fire effects on Gambel oak are important to understand because fire may be used in ponderosa pine-oak forests to accomplish various management objectives (for example, fuels reduction), or to manage oak specifically. In this note, we summarize published literature to: (1) evaluate the frequency and timing of fire in historical pine-oak forests; (2) assess effects of contemporary prescribed burning on oak survival and diameter growth; and (3) provide recommendations for managing oak directly using fire while maintaining large oaks.

Scott R. Abella, Assistant Research Professor, Public Lands Institute and School of Life Sciences, University of Nevada Las Vegas, Las Vegas, NV.
Peter Z. Fulé, Associate Director and Associate Professor, Ecological Restoration Institute and School of Forestry, Northern Arizona University, Flagstaff, AZ.

Fire and Oak's Historical Environment

Most fire-history studies have discovered that surface fires burned ponderosa pine-Gambel oak forests on average at least once every ≤13 years before policies of fire exclusion beginning in the late 1800s (table 1). One exception was an isolated 371-acre (150-ha) mesa in southern Utah that Madany and West (1983) found burned less frequently than is typical of pine-oak forests. At a northern Arizona pine-oak site exhibiting a mean fire interval of 3.7 years, Fulé and others (1997) found that 40 percent of historical fires occurred in spring (late April to June) and 60 percent in summer (July to early September). Fire-history research indicates that frequent, spring-summer fires have long been part of Gambel oak's historical environment in many southwestern pine-oak forests.

Despite the historical prevalence of fire on sites containing Gambel oak, Brown and Smith (2000) indicate that Gambel oak has low fire resistance at maturity and there is no size at which the species attains fire resistance. Simonin (2000) reported that Gambel oak bark ranges from 0.5 to 0.75 inches (1.2 to 1.9 cm) thick, categorized by Brown and Smith (2000) as "thin." However, no information was provided as to whether thickness increases with age, as it does in some oak

Table 1—Summary of surface fire frequencies before fire exclusion in ponderosa pine-Gambel oak forests. With some exceptions, pine-oak forests generally burned at least once every 10 years, similar to pure ponderosa pine forests.

Location	MFI (years)[a]	Reconstruction period	Elevation (feet)	Reference
Rincon Mountains, AZ	6 to 10	1657 to 1893	>7544	Baisan and Swetnam 1990
Camp Navajo, AZ	4	1637 to 1883	7134 to 8046	Fulé and others 1997
Grand Canyon National Park, AZ	4	1744 to 1879	7708	Fulé and others 2003a
Grand Canyon National Park, AZ	3 to 7	1679 to 1899	7360 to 7767	Fulé and others 2003b
Gila National Forest, NM	4 to 8	1633 to 1900	7639 to 8397	Swetnam and Dieterich 1985
San Juan National Forest, CO	7 to 13	1679 to 1880	7380 to 8397	Grissino-Mayer and others 2004
Zion National Park, UT – Plateau[b]	4 to 7	Pre-1881	6429 to 7888	Madany and West 1983
Zion National Park, UT – Mesa[b]	56 to 79	1757 to 1980	7052 to 7393	Madany and West 1983

[a] Range of mean fire return intervals.
[b] This study included 8994-acre (3640 ha) plateau and 371-acre (150 ha) isolated mesa study sites.

species (Peterson and Reich 2001). Nevertheless, bole charring (occasionally visible on large, living Gambel oak) likely obtained before fire exclusion in the late 1800s suggests that large oaks had at least some capacity to survive low-intensity fire (fig. 1). It is also possible that rocky microsites or other areas Gambel oak sometimes occupies burned less frequently than surrounding areas. However, this explanation does not account for oak's persistence on relatively flat, uniform sites that also burned frequently (Hanks and others 1983). Differences in fuel characteristics between Gambel oak and ponderosa pine litter are additional factors that may have allowed oak to persist on frequently burned sites. Compared to pine, looser, less resinous, and moister oak litter may have resulted in decreased fire intensity near oak boles, allowing large oaks to persevere. Such fine-scale variations in fire intensities have been recorded during contemporary burns in other oak forests (Franklin and others 1997).

In addition to some ability of large Gambel oaks to survive low-intensity fire, oaks top-killed by fire usually resprout (Harrington 1985, Kunzler and Harper 1980). Gambel oak is thus both a resister and an endurer of fire, following Rowe's (1983) classification of plant adaptations to fire. Large oaks develop some ability to survive (resist) fire, while stems top-killed by fire resprout (endure).

Figure 1—Charred bole on a Gambel oak, possibly reflecting the historical occurrence of frequent surface fires in southwestern ponderosa pine-Gambel oak forests. This site had no known history of fire after the last presettlement fire in about 1883 based on nearby research (Fulé and others 1997). Photo taken 6 miles (10 km) southwest of Flagstaff, Arizona, in the Northern Arizona University Centennial Forest. *Photo by S.R. Abella, October 21, 2005.*

Prescribed Burning Effects on Different Size Classes

To track Gambel oak survival 5 years after fall or early spring burning, we used data collected from two northern Arizona sites that are part of ecological restoration projects detailed in Fulé and others (2005) and Roccaforte (2005). Survival of oaks greater than 6 inches (15 cm) in diameter at 4.5 ft (1.4 m) exceeded 66 percent at both sites, while survival was low (11 to 20 percent) for small stems less than 2 inches (5 cm) in diameter (fig. 2). These findings reflect survival after these particular fires, and may differ from other burns conducted under different weather or fuel characteristics. Survival may also vary depending on operational aspects of burns, such as whether fuel is raked away from oak boles or if oak clumps are deliberately lit (Ken Moore, Bureau of Land Management, pers. comm. 2005). Nonetheless, these data support the conclusions of Fulé and others (2005) that large oaks can be maintained during burns, and are consistent with oak's persistence in recurrently burned pine-oak forests (table 1).

Fire Season, Frequency, and Intensity Effects

Season of burning affects both fire intensity and oak carbohydrate reserves that influence sprouting ability. Harrington (1985, 1989) tested the effects of burn season (spring [June], summer [August], or fall [October]) and frequency (one or two burns in a 4-year period) on Gambel oak in a Colorado pine-oak stand. He found that after 4 years, all burn treatments sharply increased sprout densities relative to unburned controls because of prolific sprouting of top-killed, small-diameter stems. A second burn in summer, however, resulted in the least sprouting because oak carbohydrate reserves that incite sprouting were lowest at this time. Nevertheless, it seems that burning in

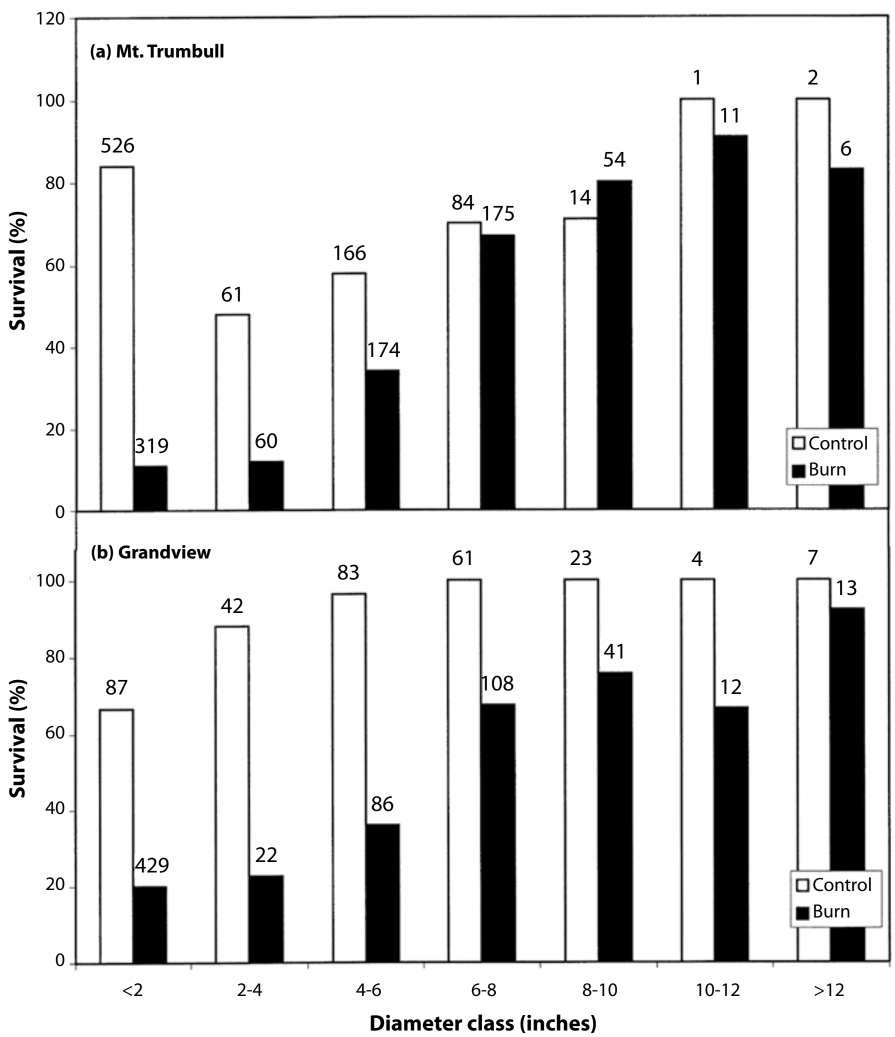

Figure 2—Survival of different sized Gambel oak stems 5 years after prescribed burning at two northern Arizona study sites in ponderosa pine-oak forests. Survival exceeded 66 percent for stems greater than 6 inches (15 cm) in diameter, while survival was low for smaller stems. Numbers at the top of each bar represent the actual number of stems in each category. The (a) Mt. Trumbull study site is on the Arizona strip and managed by the Bureau of Land Management (Roccaforte 2005). The (b) Grandview site is near the south rim of the Grand Canyon in the Kaibab National Forest (Fulé and others 2005).

any season top kills small stems and stimulates shrub-like sprouting (Harrington 1985). Continued frequent burning and top-killing would likely maintain shrubby growth forms of oak, although effects of specific burn intervals on sprouting dynamics and persistence of oak are not well known.

Several studies have reported large increases in Gambel oak dominance after intense wildfires have reduced densities of competing vegetation (Kunzler and Harper 1980, Savage and Mast 2005). This is not surprising given oak's strong sprouting ability, in contrast to many other competing species in pine-oak forests (for example, ponderosa pine). Savage and Mast (2005) proposed a successional model for pine-oak forests after severe fires that included a succession to oak shrubfields after removal of the ponderosa pine overstory. Any such intense disturbance likely promotes oak, illustrated by a similar succession to oak shrubfields after clearcutting ponderosa pine on the Beaver Creek watershed in Arizona (Ffolliott and Gottfried 1991).

Burning Effects on Diameter Growth

Large oaks have high ecological and aesthetic value, and increasing oak diameter growth may be a management objective on some sites. Onkonburi (1999) reported that prescribed burning had variable effects on oak diameter growth at 7 northern Arizona sites, but reasons for the among site differences could not be pinpointed. In her study, burning resulted in an average decrease of 0.1 inches (0.2 cm) to an increase of 0.3 inches (0.8 cm) in diameter growth among sites over a 10-year period. Fulé and others (2005) also found that burning did not significantly increase oak diameter growth 5 years after burning. However, fire effects on oak diameter growth could depend on the degree of charring damage or whether competing trees are killed or damaged. These factors likely hinge upon fire characteristics and prescriptions. Nevertheless, current data suggest that management tools other than fire, such as thinning competing pine or other trees, more reliably increase oak diameter growth (Onkonburi 1999).

Fire and the Management of Pine-Oak Forests

Fire may be used in pine-oak forests to manage Gambel oak directly or to accomplish other objectives such as fuel reduction. Because of their ecological and aesthetic value, we believe that any management strategy should strive to maintain existing large, old oaks. We offer the following suggestions to maintain large oaks during prescribed burning: (1) reduce fire intensity and duration near oak boles or avoid deliberately lighting near oaks; (2) keep pine slash away from oaks to be retained; and (3) rake fuel (particularly pine litter) away from bases of oak boles. Because fuel loads in contemporary forests are much greater than in pre-fire exclusion pine-oak forests, raking fuel is a conservative measure that may increase oak survival. If raking around old ponderosa pine already is planned, there seems little reason not to rake around old oaks as well. Several studies suggest that burning can be implemented without killing large oaks (fig. 2; Fulé and others 2005, Roccaforte 2005). In addition, particular consideration could be given to maintaining medium-sized oaks of 10 to 15 inches (25 to 38 cm) in diameter, which McCulloch and others (1965) found to produce the most acorns. It is not currently well-known how fire may affect acorn production, as production also depends on crown vigor (McCulloch and others 1965). Crown vigor could be positively or negatively affected by fire.

Fire can be used to manage Gambel oak directly to top kill small-diameter (<6-inch, 15-cm) stems (fig. 2). Densities of these small-diameter oaks may have increased in pine-oak forests since initiation of fire exclusion in the late 1800s (Fulé and others 1997). By stimulating sprouting, fire can also maintain shrub-thicket forms of oak, which are important habitat for some wildlife species (Kruse 1992, Rosenstock 1998). However, a key research need is to increase our understanding of oak stand structures and recruitment patterns that may arise after long-term burning at various frequencies.

Summary and Management Implications

- Fire is part of Gambel oak's historical environment. Oak persisted in historical ponderosa pine-oak forests that typically burned at least once every 10 years.
- Large Gambel oak exhibit some capacity to survive low-intensity fire, and stems top- killed by fire usually resprout prolifically.
- Fire of any kind is unlikely to eliminate Gambel oak from a site. Intense wildfires that remove competing vegetation often facilitate development of oak brushfields on sites formerly dominated by ponderosa pine.

- Large oaks have high ecological and aesthetic value. To help ensure survival of large oaks during prescribed burning, we suggest that managers: avoid deliberately lighting near the bases of oak boles, keep pine slash away from oaks, and rake fuel away from oaks to reduce fire intensity.
- Prescribed burning can temporarily decrease densities of small-diameter oaks, which may have increased in density since initiation of fire exclusion in pine-oak forests in the late 1800s. However, due to prolific sprouting, single burns could also result in subsequent increases in oak density. Manipulating burn frequency has potential for maintaining a variety of oak growth forms, including shrub-thicket forms of oak important for some species of wildlife.
- Other management techniques, such as thinning pine or other competing trees, appear better suited than prescribed burning for increasing oak diameter growth.

Acknowledgments

We thank the U.S. Forest Service and the Ecological Restoration Institute for funding this research, and Mick Harrington, Gerald Gottfried, Charlie Denton, and Kristi Coughlon for reviewing the manuscript.

References

Baisan, Christopher H.; Swetnam, Thomas W. 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, Arizona, U.S.A. Canadian Journal of Forest Research. 20:1559-1569.

Brown, James K.; Smith, Jane Kapler. eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.

Ffolliott, Peter F.; Gottfried, Gerald J. 1991. Natural tree regeneration after clearcutting in Arizona's ponderosa pine forests: two long-term case studies. Res. Note RM-507. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 p.

Franklin, Scott B.; Robertson, Philip A.; Fralish, James S. 1997. Small-scale fire temperature patterns in upland *Quercus* communities. Journal of Applied Ecology. 34:613-630.

Fulé, Peter Z.; Covington, W. Wallace; Moore, Margaret M. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications. 7:895-908.

Fulé, Peter Z.; Crouse, Joseph E.; Heinlein, Thomas A.; Moore, Margaret M.; Covington, W. Wallace; Verkamp, Greg. 2003a. Mixed-severity fire regime in a high-elevation forest: Grand Canyon, Arizona. Landscape Ecology. 18:465-486.

Fulé, Peter Z.; Heinlein, Thomas A.; Covington, W. Wallace; Moore, Margaret M. 2003b. Assessing fire regimes on Grand Canyon landscapes with fire scar and fire record data. International Journal of Wildland Fire. 12:129-145.

Fulé, Peter Z.; Laughlin, Daniel C.; Covington, W. Wallace. 2005. Pine-oak forest dynamics five years after ecological restoration treatments, Arizona, USA. Forest Ecology and Management. 218:129-145.

Grissino-Mayer, Henri D.; Romme, William H.; Floyd, M. Lisa; Hanna, David D. 2004. Climatic and human influences on fire regimes of the southern San Juan Mountains, Colorado, USA. Ecology. 85:1708-1724.

Hanks, Jess P.; Fitzhugh, E. Lee; Hanks, Sharon R. 1983. A habitat type classification system for ponderosa pine forests of northern Arizona. Gen. Tech. Rep. RM-GTR-97. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 22 p.

Harper, Kimball T.; Wagstaff, Fred J.; Kunzler, Lynn M. 1985. Biology and management of the Gambel oak vegetative type: a literature review. Gen. Tech. Rep. INT-179. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 31 p.

Harrington, M.G. 1985. The effects of spring, summer, and fall burning on Gambel oak in a southwestern ponderosa pine stand. Forest Science. 31:156-163.

Harrington, M.G. 1989. Gambel oak root carbohydrate response to spring, summer, and fall prescribed burning. Journal of Range Management. 42:504-507.

Kruse, William H. 1992. Quantifying wildlife habitats within Gambel oak/forest/woodland vegetation associations in Arizona. In: Ffolliott, Peter F.; Gottfried, Gerald J.; Bennett, Duane A.; C. Hernandez, Victor Manuel; Ortega-Rubio, Alfredo; Hamre, R.H., tech. coords. Ecology and management of oaks and associated woodlands: perspectives in the southwestern United States and northern Mexico; 1992 April 27-30; Sierra Vista, AZ. Gen. Tech. Rep. RM-218. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 182-186.

Kunzler, L.M.; Harper, K.T. 1980. Recovery of Gambel oak after fire in central Utah. Great Basin Naturalist. 40:127-130.

Madany, Michael H.; West, Neil E. 1983. Livestock grazing-fire regime interactions within montane forests of Zion National Park, Utah. Ecology. 64:661-667.

McCulloch, C.Y.; Wallmo, O.C.; Ffolliott, P.F. 1965. Acorn yield of Gambel oak in northern Arizona. Res. Note RM-48. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 2 p.

Onkonburi, Jeanmarie. 1999. Growth response of Gambel oak to thinning and burning: implications for ecological restoration. Flagstaff, AZ: Northern Arizona University. 129 p. Dissertation.

Peterson, David W.; Reich, Peter B. 2001. Prescribed fire in oak savanna: fire frequency effects on stand structure and dynamics. Ecological Applications. 11:914-927.

Roccaforte, John Paul. 2005. Monitoring landscape-scale forest structure and potential fire behavior changes following ponderosa pine restoration treatments. Flagstaff, AZ: Northern Arizona University. 102 p. Thesis.

Rosenstock, S.S. 1998. Influence of Gambel oak on breeding birds in ponderosa pine forests of northern Arizona. Condor. 100:485-492.

Rowe, J.S. 1983. Concepts of fire effects on plant individuals and species. In: Wein, Ross W.; MacLean, David A., eds. The role of fire in northern circumpolar ecosystems. NY, NY: John Wiley and Sons: 135-154.

Savage, Melissa; Mast, Joy Nystrom. 2005. How resilient are southwestern ponderosa pine forests after crown fires? Canadian Journal of Forest Research. 35:967-977.

Simonin, Kevin A. 2000. *Quercus gambelii*. In: Fire effects information system, [online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/ [2005, June 20].

Swetnam, Thomas W.; Brown, Peter M. 1992. Oldest known conifers in the southwestern United States: temporal and spatial patterns of maximum age. In: Kaufmann, Merrill R.; Moir, W.H.; Bassett, Richard L., tech. coords. Old-growth forests in the Southwest and Rocky Mountain Regions: proceedings of a workshop; 1992 March 9-13; Portal, AZ. Gen. Tech. Rep. RM-213. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station: 24-38.

Swetnam, Thomas W.; Dieterich, John H. 1985. Fire history of ponderosa pine forests in the Gila Wilderness, New Mexico. In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., tech. coords. Proceedings, symposium and workshop on wilderness fire; 1983 November 15-18; Missoula, MT. Gen. Tech. Rep. INT-182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 390-397.

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and series number.

Fort Collins Service Center

Telephone	(970) 498-1392
FAX	(970) 498-1122
E-mail	rschneider@fs.fed.us
Web site	http://www.fs.fed.us/rm/publications
Mailing address	Publications Distribution Rocky Mountain Research Station 240 West Prospect Road Fort Collins, CO 80526

Rocky Mountain Research Station
Natural Resources Research Center
2150 Centre Avenue, Bldg. A
Fort Collins, Colorado 80526

RMRS
ROCKY MOUNTAIN RESEARCH STATION