A FIRE FREQUENCY AND COMPARATIVE FUEL LOAD ANALYSIS IN GAMBEL OAK OF NORTHERN UTAH

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ABSTRACT

A fire history and fuels study within the Gambel oak (*Quercus gambelii*) shrub vegetation type of northern Utah found higher fuel loads and more mature to decadent stems in areas of less frequent documented wildfires. In areas of recent burns, dead fuel loads were reduced, and there was an increased cohort of younger oak stems. The clones whose stems are in a more mature to decadent state have reduced mast production, limit wildlife access and movement (Kufeld 1983), and increase the chance of having a more severe wildfire when fire does occur. The accumulations of fine fuels and larger, dead woody materials that now exist contribute to making wildfires more intense and severe when they do occur.

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INTRODUCTION

A fire history and fuels study was conducted within the Gambel oak (*Quercus gambelii*) shrub vegetation type of northern Utah to compare fuel loading between areas of varying fire frequency and recently burned and unburned sites. The urban-wildland interface nature of the study area, with its immediate proximity to a large population center, Ogden, Utah, provides ready ignition sources for person-caused wildfires. The majority of ignitions appear to be concentrated near the population centers and do not extend to the limit of the oak brush type. One objective of this study was to determine fuel loading among areas of varying fire occurrence and use the information to identify areas for natural hazardous fuels treatments while concurrently benefitting wildlife access and utilization. An additional objective was to establish a fire history to compare Native American and natural ignitions in presettlement times with present fire frequency. Comparing presettlement fire occurrences with fire frequency post-European settlement would highlight changes in fire frequency that may be attributable to shifts in cultural uses.

STUDY AREA

The study area encompassed 64,000 hectares with an oak brush dominated vegetation type along the Wasatch Mountain range on the Ogden Ranger District, Wasatch-Cache National Forest in Utah. Specifically, the study area included a western exposure of the Wasatch Mountains that abuts the large population center of Ogden, Utah and an eastern side of the range that is adjacent to a more rural but growing population and consists of three small towns, Liberty, Eden, and Huntsville, Utah. Population estimates from 1997 place the Ogden, Utah area population at 169,000 and the rural portion of the study area at approximately 5,500 (Barker 1997). Elevation of the study area ranged from 1340 meters to approximately 2133 meters.

The literature classifies the shrub portion of the study area as Fire Group Two: Montane Maple-Oak Woodland and states, "In the past, the more extensive grass cover likely permitted relatively frequent fires during the dry season" (Bradley et al. 1992). The majority of the shrub acreage is dominated by Gambel oak. The study area constitutes the northernmost reaches of Gambel oak, whose present distribution then extends south through Arizona into New Mexico (Harper et al. 1985). Gambel oak usually occurs as a low growing tree, and these oak woodlands provide wildlife habitat and protection from soil erosion. Areas dominated by oak vegetation are subject to periodic fire, and due to its ability to sprout profusely from the surviving root system, it recovers well after burning (Harper et al. 1985). The fire regime of the study area has been altered due to introduction of grazing (which reduces fine fuels), elimination of Native American burning, and active fire suppression (Bradley et al. 1992). Oak stands appear to be more extensive now than they were 75 to 150 years ago, encouraged by less frequent fires. A fire regime of low-intensity, frequent fires would have inhibited establishment of oak seedlings (Bradley et al. 1992).

A photographic history of vegetation change in the Bonneville Basin, in which the western portion of the study area lies, found that oak clones have expanded considerably since settlement, but it has been only recently that new clones have appeared (Rogers 1982). Rogers (1982) attributes this to the grazing taking place at the turn of the century as well as wildfires that inhibited the establishment of new oak clones. The new clones visible this century are attributable to the reduction and termination of livestock grazing as well as fire suppression. An area within the study area that Rogers (1982) visited showed oak clones increasing in size, and the appearance of new clones since 1901.

Gambel oak, while not highly palatable, is an important mule deer (*Odocoileus hemionus*) winter forage due to its availability and abundance (Harper et al. 1985). As well as providing forage, Gambel oak also provides cover for many wildlife species. Although it can provide necessary cover, it can grow to be too dense and impenetrable and exclude big game from the area (Kufeld 1983).

Historical and Cultural Uses

The Native American populations present in the study area before European settlement were of both the hunter-gatherer and agriculturalist traditions. The bulk of human activity was concentrated between the 1520 meter to 2130 meter elevation, in areas dominated by sagebrush (*Artemisia sp.*), juniper-pinyon (*Juniperus sp.-Pinus edulis*) and mountain brush vegetation (Harper 1986). The climate made this an area of suitable habitation for longer periods of the year than the upper or lower elevations.

Native Americans purposely burned to favor seed crops or certain plants and as an aid in hunting. Once European settlers arrived in the 1800's, the area experiencing frequent burning was reduced, first through increasing numbers of domestic livestock as settlement became widespread in the 1850's, then by the removal of the Native American people themselves. Road, trail, and canal construction in the foothills contributed to a reduction in the areal extent of fires (Harper 1986).

The introduction of domestic livestock grazing contributed to alterations in vegetative structure and diversity. Sheep numbers totalled 1,000,000 in 1885 and boomed to 3,818,000 in 1900. The Wasatch-Cache area, which includes the study area, accounted for 56% of the sheep number in 1900, or over 2,000,000 sheep. Eyewitness accounts stated that the sheep would eat everything within reach as they trailed from one bed ground to another (Peterson and Speth 1980). Permits for both cattle and sheep increased significantly in the area until about World War I. Sheep numbers declined after 1918, and Forest Service officials began to recognize overgrazing was occurring (Peterson and Speth 1980).

Overgrazing by cattle and sheep tends to reduce palatable grasses and shrubs. They are then replaced by less palatable shrubs, trees, and annual grasses. In terms of fire frequency, grazing can reduce fine fuels that would support wildfires that in turn reduce shrubs and trees. In other areas, introduced annual grasses that are able to tolerate grazing and provide fine fuels actually increase fire frequency, to the detriment of perennial grasses and forbs which cannot become established under a high fire frequency regime (Rogers 1982).

Table 1. Shrub stems within 27.9 m^2 plots counted and classified into four age classes (1992 USDA Forest Service Region 4 Range Analysis Handbook). The amount in each class was then used to relate the condition of the shrubs to the last known disturbance.

	Age class	
1	sprout/sapling	plant firmly established, smooth bark, 0.25–1.3 cm dia.
2	mature	complex branching, fissured bark, evidence of flowering or acorn production
3	decadent	+50% dead wood in crown
4	dead	no live crown, root firmly attached

METHODS

Measurement of fuel loading and determination of the parameters of fire frequency and mean fire-return interval, fuels, and age measurements were conducted in areas of known recent burns and areas where the last disturbance from wildfire was undocumented.

During the summer and fall of 1994, sampling transects were established in recently burned oak sites–1990 and 1991–and then in adjacent sites that were not documented as recent burns. The burned and unburned paired sites were similar in aspect, slope, and elevation. A total of 15 areas were sampled, including three paired burned and unburned sites. All sites were chosen according to their predominance of oak cover by using a U.S. Forest Service vegetation map. Once transects were established, two of the eight unburned sites exhibited evidence of recent burns, in approximately 1975 and 1985.

An oak fuels inventory was conducted by collecting information on dead and down fuel loading, shrub fuel loading, herbaceous fuel loading, and duff and litter depth. Using Brown's planar intersect method (Brown 1974) and methods for inventorying surface fuels and biomass (Brown et al. 1982), fuels transects were located at fixed intervals (30.5 meters) on random angles along the main sampling line. The sampling line was established on a diagonal selected to intersect oak shrubs across the sample area. The number of fuels transects read per location depended on the length of sampling line that could be established in a contiguous vegetation type and slope. Photographs were taken in association with each fuels transect. Oak stems were collected to determine age and approximate year of the most recent disturbance.

In conjunction with the oak fuels inventory, line intercept transects were conducted to measure shrub composition, canopy cover, density, age-class structure, and browse utilization. Forty lines were read in the 15 study areas, two or three per area depending on the length of the sampling line. The line intercept transects were paired with alternating fuels transects, therefore they were established every 61 meters along the main sampling line in random directions. Methods followed are described in the 1992 USDA Forest Ser-

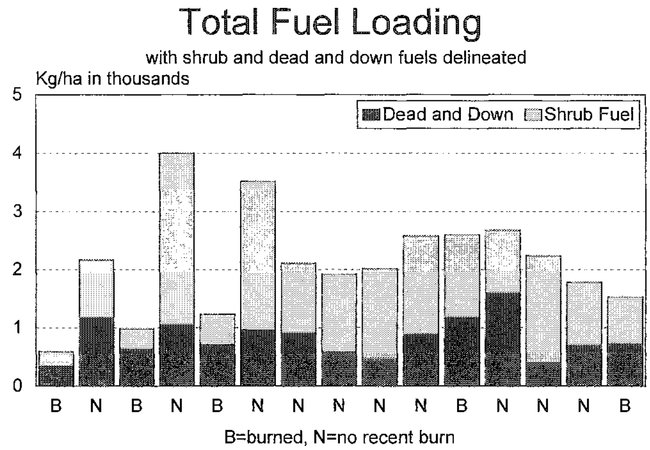

Fig. 1. Statistically, the total fuel loading among the burned area sites was significantly less than among the unburned. Total shrub fuels were also significantly different between the burned and unburned sites, with unburned areas having the higher shrub fuel load.

vice Region 4 Range Analysis Handbook(Sec. 44.5 and 44.6). Measurements of the crown spread of shrubs and trees bisected by the 30.5 meter line were recorded by species to provide an estimate of relative cover and composition. Density of woody species was calculated in a 27.9 square meter plot along the line intercept transect, where stems were counted and classified into four age classes—sprout/sapling, mature, decadent, and dead and eight classes related to browse forage availability and degree of use (Table 1).

Relative density and utilization of browse by wildlife was classified on all transects. Pellet-group counts were conducted for each area. Ungulate pellet groups were counted in fifty 1.73 meter radius circular plots along the main sampling line. The pellet group count is converted to animal days use per hectare based on the number of groups counted, hectares counted, and a defecation rate of 13 pellet groups per day.

Fire reports for the area from 1973 to 1997 were compiled and categorized by location, cause, and size.

RESULTS AND DISCUSSION

Fuels

Fuel loadings were calculated using the formulas set forth in Brown et al. 1982. Fuel loading values were compared among transect locations for burned and unburned areas and ranged from 590.86 kilograms per hectare on a burned site to 4001.8 kilograms per hectare on an unburned site (Figure 1). These values include dead and down fuels and shrub fuels. To test for a significant difference between fuel loadings on burned and unburned plots, an analysis of variance ($F_{0.5,1,13}$) found burned area fuel loadings were significantly less. Total shrub fuels were also significantly different between the burned and unburned sites according to an analysis of variance between the means, with unburned areas having the higher shrub fuel load. Shrub fuel loadings ranged from 242 kilograms per hectare with 11% dead to 2948 kilograms per hectare with 9% dead (Figure 1).

Oak Cover

There was no significant difference in measured oak canopy cover between burned and unburned sites based on an analysis of variance for the means ($F_{0.5,1,13}$) (Figure 2). The range was 44% to 54% cover on burned lines, and 32% to 69% oak cover on the unburned lines. The highest percentage of oak cover was

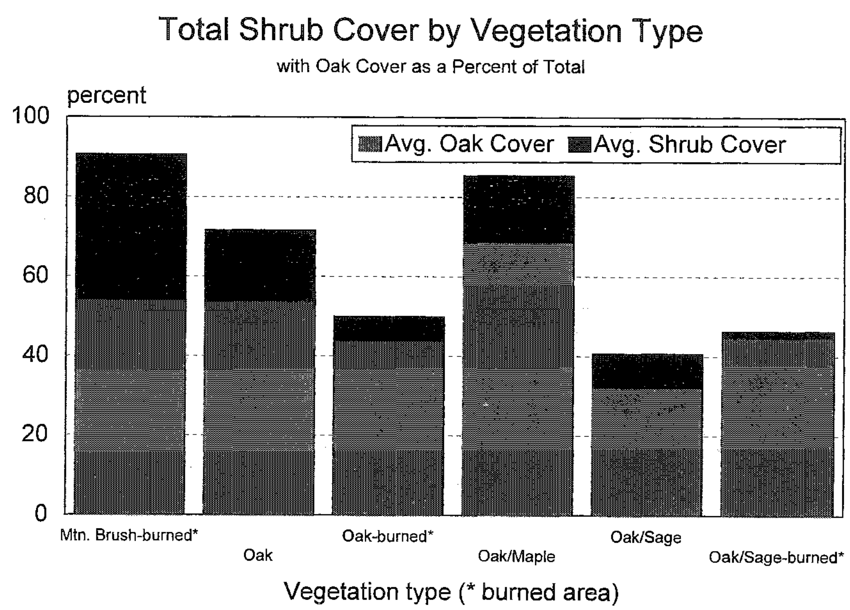

Fig. 2. The highest percentage of oak cover was found on unburned lines in the oak-maple (*Acer grandidentatum*) vegetation type. Welsh (1987) describes the mountain brush community as a mix of Gambel oak, bigtooth maple, serviceberry (*Amelanchier alnifolia*), mountain mahogany (*Cercocarpus ledifolius*) and big sagebrush.

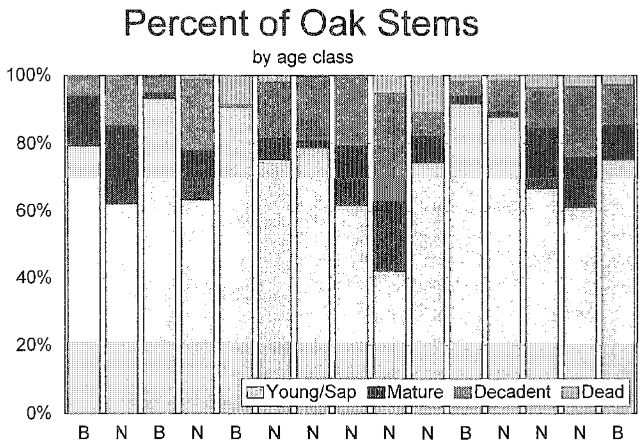

Fig. 3. The majority of oak stems for all 15 transects were in the sprout/sapling state. In recently burned areas, a higher percentage of the total composition of oak stems occurred in the sprout/sapling age class, while areas not recently burned had a slightly higher percentage in mature and decadent stems. B=area burned recently, N=area not documented as burning within at least ten years.

found on unburned lines in the oak/maple (*Acer grandidentatum* Nutt.) type. The patchy distribution of oak in the oak/sage (*Artemesia tridentata* Nutt.) vegetation type resulted in a lower percentage of oak cover along those lines. Total shrub intercept was highest on the oak/maple and in the mountain brush community. Welsh et al. (1987) describe the mountain brush community as a mix of Gambel oak, bigtooth maple, serviceberry (*Amelanchier alnifolia* Nutt.), mountain mahogany (*Cercocarpus ledifolius* Nutt.) and big sagebrush. Other shrubs commonly associated with the mountain brush mix on the study area included chokecherry (*Prunus virginiana* L.), and snowberry (*Symphoricarpos oreophilus* Gray).

Oak Age Class

The majority of oak stems for all 15 transects were in the sprout/sapling stage. In recently burned areas, a higher percentage of the total composition of oak stems occurred in the sprout/sapling age class, while areas not recently burned had a slightly higher percentage in mature and decadent stems (Figure 3). The highest density of young stems was recorded on a recent burn transect, dating to 1985. The highest number of mature stems occurred in an unburned site as did the highest number of decadent stems. The lowest density of decadent stems was found in recently burned areas. An analysis of variance ($F_{0.5,1,13}$) comparing the means showed no significant difference in the number of sprout/saplings or mature stems between burned and unburned sites, however the number of decadent stems was significantly higher in the unburned sites (Figure 3). The clones whose stems are in a more mature to decadent state have reduced mast production, limit wildlife access and movement (Kufeld 1983), and increase the chance of having a more severe wildfire when fire does occur.

Wildlife Use

The majority of big game sign was identified as mule deer (*Odocoileus hemionus*), which occurred in 9 out of 15 locations, followed by elk (*Cervus elaphus*), and then moose (*Alces alces*). Deer abundance was consistently higher on sites with less than 50% oak canopy cover.

The lack of deer sign or minimal occurrence in areas that are known to be important winter range may be attributed to low deer numbers related largely to recent winterkill, encroaching human populations, and disturbance of remaining habitat. Lack of use may also be attributed to the impenetrability that occurs with increasing oak canopy cover (Kufeld 1983).

Fire Occurrence

Ogden Ranger District documentation reported 173 fires from 1973 to 1997 in the study area. Fire sizes ranged from 0.04 hectares to 1282.9 hectares. People were responsible for 123 of these fires; the remaining 50 were lightning-caused. The majority of burned hectares are a result of 14 person-caused fires occurring in the last 10 years. These fires averaged 247.7 hectares per fire over a total of 3465 hectares with a range of 21 to 1282.9 hectares. The remaining 109 person-caused fires burned 24.5 hectares or 0.22 hectare per fire with a range of 0.04 hectares to 14.2 hectares.

The 50 lightning-caused fires burned a total of 5.3 hectares, or 0.1 hectare per fire with a range of 0.04 hectares to 2.02 hectares. All of these fires were actively suppressed or monitored until they burned out. Some lightning fires may have gone undetected. However, the population concentration in this area contributes to early and rapid detection. If there were lightning strikes that went undetected they were obviously very small or immediately suppressed due to natural conditions.

Oak stem ages were variable and did not indicate a stand-replacing event in the areas without recent documented wildfires. However, areas with recent large documented wildfires experience stand-replacing fire intensities, in which the oak overstory is killed. Therefore, fire frequencies were not assigned to individual sites due to the lack of even-aged oak sprouts that indicated a stand-replacing event (Harper et al. 1985). Fire frequency was based on the number of ignitions in individual areas.

The combined fire frequency, lightning plus person-caused, equals 7 fires per year, ranging from 1 to 16 fires per year. The person-caused frequency was 5 fires per year, ranging from 0 to 13 fires per year, and lightning-caused fires had a frequency of 2 fires per year with a range of 0–7 fires per year (Table 2). Fire frequencies appear to be very high (approximately 7 ignitions per year) because of the number of ignition sources originating from the urban-wildland interface.

Mean Fire-Return Interval

The return interval for lightning-caused fires is very short, every 4 months or twice during the burning

Table 2. A combined fire frequency, lightning plus person-caused, equals 7 fires per year, ranging from 1 to 16 fires per year. Fire occurrence is so frequent, with multiple fires often occurring on the same day, that return interval calculations are based on an 8-month burning period of March to October.

Cause	Fire frequency	Mean fire-return interval
Lightning	2 (range = 0–7)	4 months
Human	5 (range = 0–13)	1.6 months
Combined	7 (range = 1 to 16)	1.1 months

Table 3. The westside of the study area, near the larger population concentration, experienced 74% of its ignitions from humans whereas 60% of ignitions on the eastside were person-caused.

Location	Cause	Number of fires	Percent of fires
Eastside	Lightning	18	35%
	Person	33	65%
Westside	Lightning	32	26%
	Person	90	74%

season of March to October. When person-caused fires are added, the return interval shrinks dramatically to 1.1 months or 7 times during the burning season. These values represent the fire-return interval for the entire study area, approximately 64,000 hectares in size. Insufficient data were collected to establish return intervals at individual sites. Even without person-caused fires, the mean fire-return interval is frequent enough to supply the necessary ignitions for a high frequency fire regime.

The present combination of ignitions and subsequent acres burned accounted for an average of 139.6 hectares burned per year. However, these are person-caused fires in high hazard areas that experience repeated fires. Suppression efforts remove the natural random process of lightning fires in areas that require the disturbance to remain diverse and healthy. All of the recent large fires have occurred in areas near population centers or directly adjacent to human developments. The west side of the study area, near the larger human populations, experienced 74% of its ignitions from humans, whereas 65% of ignitions on the east side were person-caused (Table 3). A more telling figure is the total number of fires, 122 near the population center, with 51 fires away from it. Several of the urban-wildland interface fires burned in overlapping areas, and three wildfires were limited in growth by adjacent recently burned areas. The present regime of frequently repeated fires in these high hazard areas decreased diversity by favoring plants that thrive on frequent disturbance through post-fire regeneration strategies of mass seeding such as cheatgrass *(Bromus tectorum)* (Young et al. 1987), and damaging soils and root systems that protect a valuable watershed. Single fires may encourage oak to sprout prolifically, but repeated annual burns may actually inhibit growth (Harrington 1985). Oak is most harmed by fires during the summer growing season when carbohydrate reserves are low (Harrington 1985). The majority of fires in the study, 103 out of 173, or 60%, occurred during July and August (Figure 4). Seventy-four percent of lightning fires ignited during this 2-month period and 54% of all person-caused fires started during July and August. The percents misrepresent the effect of human ignitions, as far more person-caused fires burned in 25 years during July and August, 66 fires compared to 37 lightning strikes (Figure 4).

The eastern portion of the study area is experiencing fewer fires, but it also suffers from repeated fires in urban-wildland interfaces. While in other areas of the eastern section, fire suppression efforts have been so successful with both lightning- and person-caused ignitions, that the oak clones suffer from decadence

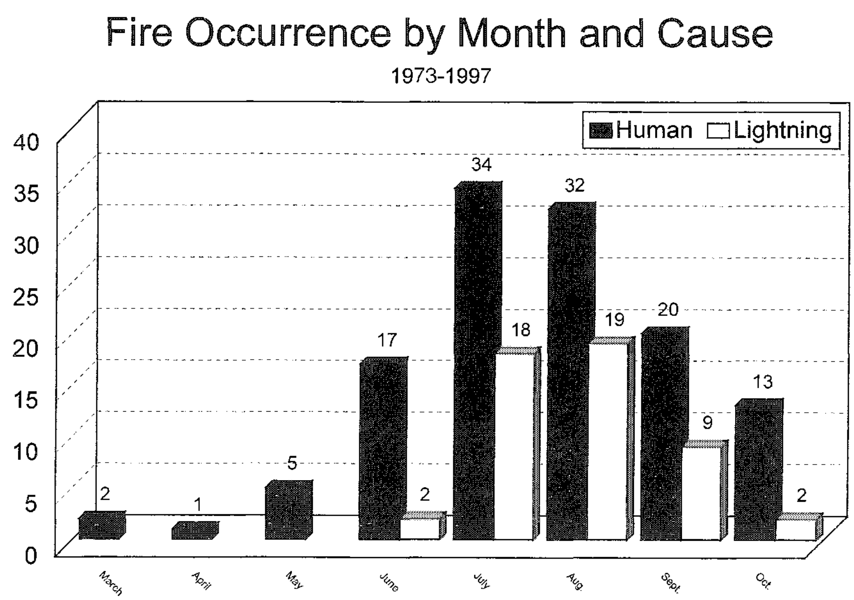

Fig. 4. The majority of fires in the study area, 103 out of 173, or 60%, occurred during July and August. Consequently, most wildfires are occurring during the summer growing season when carbohydrate reserves are low (Harrington 1985), and disturbance the most damaging to the shrub.

and too little disturbance. The accumulations of fine fuels and larger, dead woody materials that now exist contribute to making wildfires more intense and severe when they do occur. Before wildland fire suppression, more frequent fire would have maintained the dead fuel load in a more reduced state. On the west side of the study area, where 74% of ignitions are people-caused, areas are burning frequently and repeatedly.

CONCLUSIONS

The concentration of fire ignitions dictate that some areas burn frequently, while suppression activities and lower human populations mean other areas burn less frequently. Historical data were not available to adequately compare presettlement ignitions to post-European settlement numbers. There are historical accounts of Native Americans burning in the area and this burning was drastically reduced, if not eliminated, by the removal of the Native Americans themselves, as well as introduced domestic livestock grazing. These two factors, related to European settlement, decreased the number of ignitions and the potential spatial impact of the wildfires. Suppression activities also reduced the impact of fire, but now, as populations grow and expand, ignitions are frequent in some areas, while suppression reduces the spatial effect of fire in others.

As the present trend continues, those areas with high fire frequencies, and those with small burned acreages, will probably become more uniform. With a decrease in diversity, recovery will be much slower when disturbances occur. For example, as oak increases in those areas with longer fire-return intervals, a defoliating insect would have a far more detrimental effect than in an area with a diverse vegetation cover. Conversely, those areas with frequent ignitions and areas that burn repeatedly face a loss of woody species, an increase in exotic species, and potential losses of wildlife habitat.

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