

Restoration Management of Northern Oak Woodlands¹

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Abstract: Northern oak (*Quercus garryana*) woodlands at Annadel State Park are experiencing an invasion of Douglas-fir (*Pseudotsuga menziesii*) owing to changes in livestock grazing, firewood cutting, and fire suppression occurring since before the park was established in 1972. To curtail this invasion, a restoration management plan was developed based on studies of northern oak and Douglas-fir seedling establishment, stand-age analysis, and fire history. Management techniques involved in the restoration plan include prescribed burning, manual removal of Douglas-fir saplings, and girdling of larger Douglas-fir trees. Results of the management activities to date are reported in terms of the area of northern oak woodlands treated; the numbers of Douglas-fir trees, saplings, and seedlings killed by treatments; and changes in understory conditions including oak (*Quercus garryana*) and bay (*Umbellularia californica*) seedling establishment.

Annadel State Park is located in Sonoma County, California, approximately 1 mile east of Santa Rosa. The Annadel State Park brochure describes the park as “a wilderness at your doorstep.” Annadel is one of the largest State Parks in Sonoma County. The park unit encompasses 5060 acres of land located in the heart of a growing metropolitan area of approximately 250,000 residents. It is bounded on the east by the Valley of the Moon, on the north by Rincon Valley, and on the south and west by Bennett Valley. It is visited annually by between 150,000 to 170,000 hikers, equestrians, mountain bikers, and runners.

Annadel State Park includes significant historic, archeological, geologic, wildlife, and vegetation features. One hundred twenty Native American and historic Euro-American sites have been recorded. Most of the Native American sites are associated with the processing of stone material to make tools. The many historic Euro-American sites found within Annadel consist of andesite and basalt quarries, rock walls, fence lines, homestead foundations, and access roads. The vegetation of the park is typical of the southern North Coast Range, with representation of coastal prairie, chaparral, northern oak woodland, mixed evergreen forest and coniferous forest community types (Amme 1987).

It is the policy of the California State Parks to prescribe and execute a program of resource management based on current and continuing scientific research. This management is designed to perpetuate a park’s unique values. Research conducted during the late 1980’s at Annadel documented several vegetation changes within the park. These investigations included a characterization of the park’s vegetation types, an assessment of forest, woodland, chaparral and grassland fuels, and the effects of prescribed burning on these fuels and vegetation. Further studies included stand age analysis within the forest and woodland types, factors responsible for the establishment of tree seedlings and a fire history of the park (Barnhart and others 1996). Permanent plots were established to observe the response of the oak woodland type to management activities.

Some of the finest examples of the northern oak woodland within California are found at Annadel. Approximately 1050 acres of this northern oak woodland dominated by Oregon white oak (*Quercus garryana*) are threatened by the invasion of Douglas-fir (*Pseudotsuga menziesii*). Causal factors which fostered the establishment of Douglas-fir include changing understory conditions owing to increased oak densities and the suppression of fires in recent decades (Barnhart

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and others 1987). Stand age analysis revealed that all oak species sampled within the park were consistently much older than the oldest Douglas-fir observed (Barnhart and others 1996). During the past 50 years, fire exclusion in these sites encouraged Douglas-fir invasion into the oak woodland. In turn, the oak woodland has succeeded to the Douglas-fir type where the Douglas-firs have overtopped the oaks, resulting in oak mortality.

The historical fire frequency within the Sonoma Valley and Annadel has been analyzed through fire scars on redwoods adjacent to northern oak woodlands. Finney and Martin (1992) reported that the mean fire intervals from all stumps varied from 6.2 to 20.9 years, with many intervals between 2 and 10 years. The northern oak type flourished under this historical regime of relatively low-intensity frequent fire. Since the early 1900's modern fire suppression activities prevented most fires within the Sonoma Valley from spreading. Only two lightning-caused ignitions have been recorded since 1939. It is unlikely, though, that lightning was the sole ignition source responsible for the short fire intervals before settlement. Several sources document the indigenous use of fire. The short fire intervals evidenced at Annadel suggest the surface fuels and understory vegetation were systematically and intentionally burned by Native Americans. The impacts of consistently short fire intervals recorded between the late 1300's and mid-1800's would have markedly influenced the composition and structure of the park vegetation (Finney and Martin 1992). Since 1939, when fire records were first maintained, 39 fires have burned within Annadel's boundary. Most of these were suppressed as small fires less than 2 acres in size. The approximate 50 years of fire suppression have allowed Douglas-fir to be spared fire-caused mortality. As a result of the expansion of Douglas-fir, essential wildlife habitat, biodiversity, and the open character provided by the park's oak woodlands are being lost.

Development of a Restoration Method

Documentation of the Douglas-fir invasion at Annadel State Park (Barnhart and others 1987, Barnhart and others 1996) led park officials to initiate an active oak woodland management program during the late 1980's. Prescribed burns were conducted within targeted high-priority locations in the park. Manual removal of Douglas-fir also took place. Approximately 460 Douglas-fir trees, 6 inches DBH (diameter at breast height) and larger, were marked within a 550-acre area of oak woodland. Private contractors applied a 50 percent solution of glyphosate, under the trade name of Roundup, to shallow frill cuts made into the cambium layer. Smaller-diameter Douglas-fir trees were felled, with the slash lopped and scattered within the same 550-acre area. A 100-ft visual buffer zone was established adjacent to the park roads and trails within the management area. Within this corridor, no Douglas-firs were treated to ensure that trees would not be killed in areas that were highly visible.

Manual Tree Removal

In 1993, after several years of curtailed activities due to park budget constraints, increased attention was again given to Annadel's oak woodlands. A volunteer team was formed to complement prescribed burning efforts. Trained in the safe operation of chain saws and hand tools, the volunteers applied frill cuts to Douglas-fir trees with more than 6 inches DBH. This was accomplished by applying a single chain saw cut through the cambium of the tree. No herbicide was applied. Smaller trees were felled, and the slash was lopped and scattered. Many very small trees were simply pulled out of the ground. Average attendance at monthly team work parties was between 8 and 12 volunteers. Additional

volunteers were actively sought to augment the initial core group of team members. Approximately 100 acres were treated during the first year the volunteer team was in place. A preliminary assessment of frill-cut tree mortality was conducted in 1994 and 1995.

Prescribed Burning

The acreage of prescribed burning has greatly increased since the program was initiated in the 1980's. In July 1994, a 242-acre compartment of oak woodland was burned. The burn was accomplished on 2 consecutive days. The fire was started around the perimeter of the compartment. Complete ignition around the perimeter was achieved within a few hours. This allowed the interior fuels to burn out as wind and topography dictated. The weather for July was ideal: high temperature was 88 °F; minimum relative humidity was 30 percent with mild winds. The second day's firing operations were conducted in much the same way. Ignition occurred along two concurrent flanks with a perimeter fired out within a few hours of the initial ignition. Again, the interior fuels burned out over the next several hours. A subsequent survey of the area indicated about 2 percent of the area within the burn boundary did not burn.

An additional 95 acres were burned during similar conditions during July 1995. The high temperature was 89 °F, with the minimum relative humidity of 29 percent. Winds were very calm, which prohibited active fire spread in some locations. This weather, coupled with the insufficient fuel provided by oak litter and Douglas-fir needles, left approximately 5 percent of the burn compartment with live Douglas-fir remaining following the burn.

Post-Fire Assessment

A post-burn monitoring protocol was developed immediately after the 1994 burn. Twenty-three transects were installed to assess tree seedling and sapling survival and post-burn seedling establishment. Seedlings were defined as plants less than 2 ft tall. Saplings were defined as plants more than 2 feet tall but less than 10 ft in height. Transects were 10 feet wide and ran from one side of the burn to the other along north-south lines. Data were recorded for 100-foot long sections of each transect.

Results

Manual Tree Removal

The results of the Douglas-fir killing contracts from the 1980's are variable. All of the trees treated with shallow frill cuts and herbicide died. Establishment of a visual buffer zone adjacent to the park roads and trails proved to be a poor management decision. Douglas-fir seed production from trees in the buffer zone continued, and currently a dense stand of Douglas-fir survives the contracted work. In addition, many of the smaller trees felled during this time have not died. The stumps were left too high, and dormant buds below the cuts were stimulated to produce new shoots. These new shoots have become new trees in many cases.

The results of the volunteer teamwork within the treated 100 acres are generally very favorable. One year after treatment, the girdled Douglas-fir trees have thinning crowns, needle discoloration, and needle drop. Some trees are dead. A few isolated Douglas-fir trees of 12-inch DBH or greater have not been killed by the girdling work. Some of the cuts made with chainsaws were too shallow to sever the cambium layer. If chainsaw cuts are deep enough, herbicide use is unnecessary. All trees properly treated will die. The new Douglas-fir trees that have become established within the treatment areas, along with the dense

Douglas-fir regeneration along the park roads and trails, are being treated by volunteers. Currently, volunteers are taking great care to remove all Douglas-fir, regardless of their location within the oak woodland, and to make cuts below the lowest branch node.

Prescribed Burning

Post-fire data collected in 1994 showed an average mortality of 38.9 percent for seedlings of Oregon white oak, 28.5 percent for California bay, and 87.9 percent for Douglas-fir (table 1). In the 1995 re-survey of the 10 transects, the number of oak seedlings increased by 9.2 percent to an average of 52.3 seedlings per acre as a result of new seedlings established after the fire. California bay seedling

Table 1—Seedling populations and fire-caused mortality occurring in the 1994 prescribed burn compartments at Annadel State Park

Species	Number of seedlings before prescribed fire	Number of seedlings killed by prescribed fire	Fire-caused mortality	Number of seedlings alive in 1994 after fire	Number of seedlings alive in 1995
	<i>no./acre</i>	<i>no./acre</i>	<i>pct</i>	<i>no./acre</i>	<i>no./acre (pct)</i>
<i>Quercus garryana</i>	78.4	30.5	38.9	47.9	52.3
<i>Umbellularia californica</i>	61.0	17.4	28.5	43.6	52.3
<i>Pseudotsuga menziesii</i>	143.7	126.3	87.9	17.4	8.7

populations increased 19.9 percent to 52.3 per acre, while the number of Douglas-fir seedlings decreased 50 percent to 8.7 per acre.

As is generally the case in understory burning, both the 1994 and 1995 prescribed fires burned in a mosaic of lesser and more severe fire intensities, because of uneven distribution of surface fuels. Oak leaf litter and Douglas-fir needles produce poor surface fuels to carry a fire on the forest floor under the live tree canopy. In contrast, native California fescue (*Festuca californica*) produces high volumes of flammable grass fuel. Those locations occupied by California fescue burned with high intensity. Where surface fuels allowed fire to spread, Douglas-fir seedling mortality was near 100 percent. Approximately 2 percent of the area along the transects through the 1994 prescribed burn area did not burn because of sparse surface fuels. Nearly all of the Douglas-fir seedlings that survived the prescribed fire were observed in these unburned areas.

Discussion and Conclusions

The general resource management strategy for the park is to dovetail prescribed burning with volunteer or funded hand labor projects. Manual removal of Douglas-fir seedlings and saplings must be accomplished in portions of the oak woodland that are not affected by burning. Girdling of larger Douglas-fir will be required where trees survive burning. Our experience since 1994 shows that relatively small numbers of volunteers, with proper training, can be effective over time. Prescribed fire is very reliable in reducing Douglas-fir invasion in fuels dominated by California fescue, but is less reliable in sparse fuels such as oak leaf litter and Douglas-fir needles.

The prescribed burning prescriptions used at Annadel were developed after many years of field experience in burning the fuel types represented within the park, coupled with advanced fire behavior calculations training. The BEHAVE family of fire behavior prediction models (Burgen and Rothermel 1984) was used to quantify predicted fire behavior during burning. The nature of surface fuels within the park is extremely variable, and site-specific burning prescriptions are always necessary to ensure that prescribed burning is conducted in a safe manner, while satisfying burn objectives. The weather recorded during the 1994 and 1995 burns represented warm, yet moderate, burning conditions for Annadel.

Burning at this location can still be safely conducted with temperatures as high as 89 °F until the relative humidity drops to 25 percent. Burning when the relative humidity falls below 25 percent makes controlling and containing a prescribed fire at Annadel much more difficult and provides a more limited margin of safety. Wind measurements are also crucial for developing a burning prescription. Surface winds in excess of 10 miles per hour make it difficult to contain fire spread and intensity.

Prescribed burning experience at Annadel has demonstrated that fall burning at this location is not entirely appropriate. After the fall rains, the composition of surface fuels precludes adequate fire spread. The relatively non-flammable oak leaf litter and Douglas-fir needles will sustain surface fire only under the driest conditions. Burns can be conducted in the fall, just before the first rains, because live and dead fuel have reached critical moisture levels. Burning in early or midsummer can be most effective and can also provide 2 to 3 months of fire protection for the homes in the urban interface around park boundaries.

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