Restoring fire to Baker Cypress populations in northern California.

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ABSTRACT

Many fire-adapted plant communities cannot survive extended periods of fire suppression. Baker cypress (*Cupressus bakeri*), a rare serotinous conifer known from only a handful of locations in northern California, is thought to depend on fire for seed dispersal, and to require post-fire conditions such as bare mineral soil and direct sunlight to germinate. Fire has been excluded from many sites supporting *C. bakeri* for decades and most populations show no evidence of regeneration. In 2006 we began a study to examine how prescribed burning and thinning treatments affect cypress regeneration and to identify factors that influence cypress recruitment. In the first year of this project we collected pre-treatment data at seven *C. bakeri* occurrences across northern California. We found large variation in the status of these populations. Some sites were characterized by decadent, even-aged stands, while other sites appear to support healthy, multi-aged populations. We observed few seedlings at sites that had not experienced recent fires suggesting that fire is critical for recruitment. We also found fewer cones in densely populated stands and preliminary measures of seedling viability were low. Next year we will collect post-treatment data at sites where prescribed burning and thinning treatments are being implemented and at two sites where wildfires occurred since the project began. The information we collect will not only fill gaps in our understanding of *C. bakeri*, but will also help us to develop recommendations for restoring fire to cypress and other fire dependent communities across northern California.

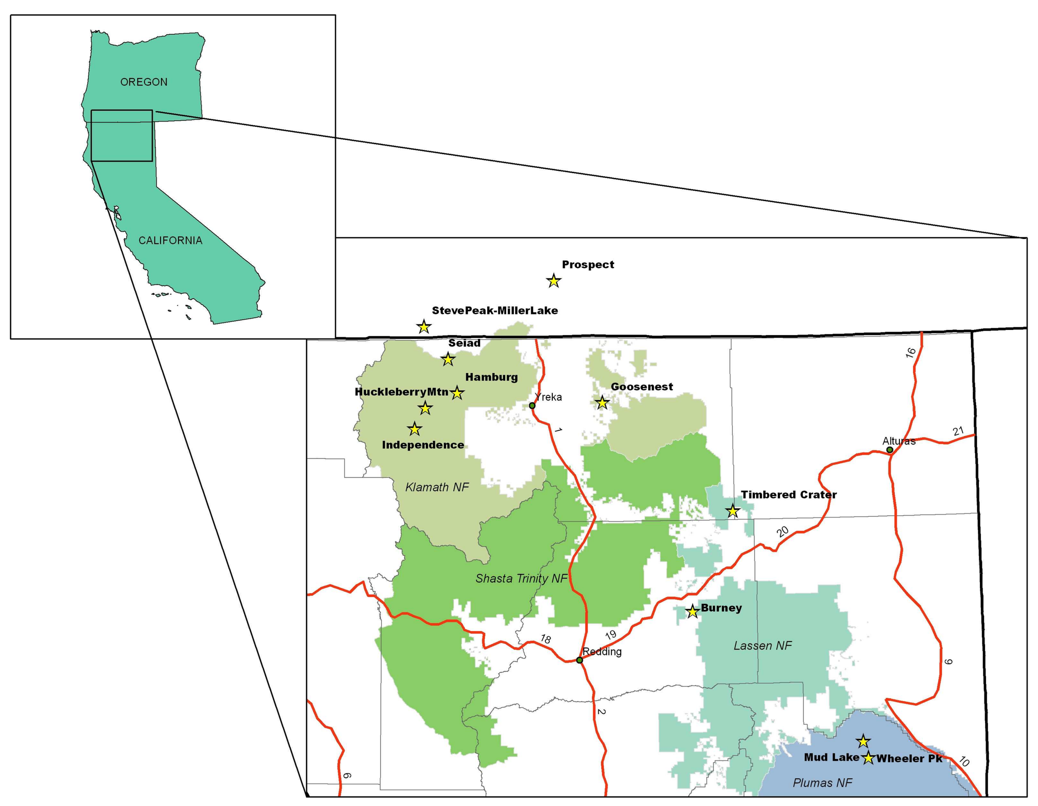

Figure 1. Known occurrences of Baker Cypress

INTRODUCTION

The USDA Forest Service is currently implementing fuels treatments, including prescribed burning, across a range of vegetation types in northern California. There is very little information about how these treatments will affect rare and endemic plant communities. In many cases these plant communities are not included in prescribed burning programs because of lack of information, yet many fire-adapted plant communities cannot survive extended periods of fire suppression. For example, Baker cypress (*Cupressus bakeri*) bear closed or serotinous cones that depend on fire for regeneration, and cypress seeds need bare mineral soil and direct sunlight in order to germinate (Vogl et al. 1977). Fire has been successfully excluded from many sites supporting cypress populations for almost a century. Many cypress stands are now densely crowded by shade-tolerant species, and mature adult cypress are dying with almost no evidence of regeneration. Management actions to stimulate cypress regeneration must be taken at these sites if cypress populations are to persist there (Wagener and Quick 1963, Keeler-Wolf 1985). There is currently an urgent need to restore fire to these rare and endemic plant communities before they are extirpated.

Adult cypress are often killed by fire, so federal land managers risk extirpating cypress occurrences by conducting prescribed burning programs that do not adequately promote cypress regeneration. However, USDA Forest Service and Bureau of Land Management (BLM) managers lack critical information to ensure efforts to restore cypress populations will be successful, such as:

- At what fire return interval and/or stand age should prescribed burning be conducted to ensure cypress regeneration?
- How does fire severity affect cypress regeneration?
- Can fire surrogate treatments promote cypress regeneration?
- Are certain environmental conditions associated with cypress regeneration?

Ten species of cypress are native to California, 8 of which are endemic (Hickman 1993). These species are found in disjunct and isolated populations throughout California, and may represent relicts from an earlier, more mesic climatic regime when cypress were more widely and continuously distributed (Axelrod 1977). Cypress often occur on infertile soils such as serpentine, and a number of endemic and rare plant species are associated with cypress at these sites (Vogl et al. 1977, Kruckeberg 1985).

Baker cypress occurs in approximately 10 general locations scattered across the northern Sierra Nevada, Cascade, and Siskiyou Mountains. The Siskiyou occurrences are found on serpentine and granitic soils, while in the Sierra Nevada and Cascade ranges Baker cypress is found on volcanic substrates (Esser 1994). Baker cypress occurs at elevations from 3795 to 7042 feet on north to northeast facing slopes, and is associated with chaparral, mixed evergreen and montane coniferous forest vegetation types (Wolf 1948, Esser 1994). Baker cypress is a California Native Plant Society list 4 species (species of limited distribution), and a Special Target Element in Region 5 of the USDA Forest Service.

Baker is highly fire dependent (Vogl et al. 1977, Esser 1994). They possess closed or serotinous cones that open in response to fire, and seeds that require high light and exposed mineral soils characteristic of burned areas to germinate (Vogl et al. 1977). Cypress usually grow in even aged stands, suggesting that most populations germinate in single cohorts after fires (Ne'eman et al. 1999). Adult Baker have thin bark and are easily killed by fires. They retain numerous dead lower branches, and often grow in dense thickets which are conducive to crown fires. Because of these factors, fires often kill all mature cypress trees in the stand (Stone 1965, Silen and Olson 1992).

Cypress species lack the ability to resprout, and therefore cypress populations must reestablish from seed. It is believed that cypress seeds have very limited dormancy once they are dispersed from the cone, so the primary seed source for post-fire regeneration comes from seeds accumulated inside cones (Esser 1994). Such fire dependent obligate seeding species are sensitive to fire return interval because it largely determines the size of this seed bank (Ne'eman et al. 1999).

This proposed study will evaluate the effect of fire surrogate treatments such as thinning and masticationon cypress regeneration. Many cypress stands are now growing in dense stands with heavy fuel loads. At some sites there is a need to reduce fuels to allow for the safe implementation of prescribed burning, and in some cases prescribed burning may not be feasible. It is not known if thinning alone can promote cypress regeneration. There is evidence that some cypress cones may open in the absence of fire, and some seedlings can establish in isolated patches where conditions are suitable. However, cone opening in the absence of fire is thought to be slow and infrequent, while post-fire cone opening is rapid and uniform, releasing large numbers of seeds (Wolf 1948, Zedler 1986).

Location	National Forest	Estimated Size (acres)	Elevation	Soil Type
Seiad	Klamath	800	3,000-3,800	ultramafic
Independence	Klamath	5	4,800	granitic
Huckleberry Mtn.	Klamath	40	3,800-4,600	ultramafic
Goosenest Mtn.	Klamath	300	5,000-6,000	volcanic
Hamburg	Klamath	16	4,400-5200	ultramafic
Mud Lake / Wheeler Pk	Plumas	307 / 73	6,400-6,900	volcanic
Hat Creek / Burney	Lassen		4,500-5,000	volcanic
Timbered Crater	Lassen/BLM	7,000	3,500-4,000	volcanic
Flounce Rock-Prospect, OR	Rogue Siskiyou	< 5	4,000	metasedimentary
Steve Peak, OR	Rogue Siskiyou	< 50		metasedimetary

Figure 2. Description of Baker cypress populations

METHODS

Data were collected from seven sites in Northern California on the Klamath, Lassen, and Plumas National Forests as well as the Bureau of Land Management Alturas resource district. At each location three to five random 1/5th acre plots were established depending on the size of the *C. bakeri* stands. We recorded the species, diameter, height, and crown condition class for all trees with a DBH greater then 4 inches within each 1/5th acre plot. To estimate seedling and sapling densities, we recorded the species and diameter class for all saplings taller than 4.5 feet as well as the species and height class for all seedlings uder 4.5 feet tall within a $1/10^{th}$ acre radius at the center of the larger plot.

Figure 3. Baker cypress at Seiad

We selected six *C. bakeri* individuals representing the entire range of size classes present within a stand. Cores were collected at the lowest possible location along the bole. We also estimated the number of cones per tree as well as the percentage of closed cones We collected a branch from each of these six trees and selected ten cones and placed in individual paper bags for processing in the lab.

Vegetation cover was measured using 1-meter quadrat frames placed at standard locations along transects radiating from plot center. Within each meter frame, we recorded the species and percent cover of all herbaceous plants as well as the percent cover of litter, rock, bare ground, moss, coarse woody debris (CWD), live tree bole, and scorch if the plot was burned. We also measured the canopy cover at each meter square location by taking the readings from a spherical densiometer at each side of the meter square. In addition to vegetation data, we also measured fuels data using modified Brown's transects.

In order to determine the age of the *C. bakeri* stands, we counted the rings on the cores taken from each plot. Each core was air dried for two weeks, mounted in a core holder and then sanded with find grade sandpaper in order to facilitate an accurate ring count using a dissecting microscope.

To understand the rates of regeneration we measured the age of serotinous *C. bakeri* cones by counting the rings of the branch supporting the cone. This number of rings should correspond to the age of the cone on the tree. We then counted the number of fully developed and underdeveloped seeds present in each cone, and whether it was closed, open or partially open at the time of collection. We then tested a sample of 20 fully developed seeds from each cone by exposing them to a tetrazolium staining agent (ASOA. 2000).

RESULTS

In general, the density of trees within a plot is dependent on the time since last fire. Plots without recent fires tended to have fewer Baker cypress of any age. These plots either contained a greater proportion of other conifers, mostly white fir with a few scattered Baker cypress, such as at Mud Lake, or in harsher ultramafic soils, like Seiad and Huckleberry, sites without a recent fire history tended to have only a sparse cover of older trees. Plots that had recent fires tended to contain a high density of seedling and saplings.

The variation in the plots that we found at Seiad gives a good example of these differences (Fig 4.). Two fires have burned through Seiad in the last 60 years – one in 1951, and one in 1987. The 1987 fire burned the south end of the stand and consisted of small spot fires that left large patches of existing vegetation untouched. A plot conducted within this area (Seiad1), contained only a few trees but lots of small saplings (20) and a heavy brush layer. In contrast, the 1951 fire occurred at the north end of the stand and burned at high intensity. A plot at the north end of the stand (Seiad5) consisted of a high density of seedlings and older saplings, with only 9 Baker cypress having a DBH greater than 4". At the south end of the population another plot (Seiad2) represented a decadent group of trees with no recent fire history. We were unable to age the surviving trees in this plot because of the high amount of rot in the core samples. For comparison, the data collected after the 2006 fire in Independence Valley shows the high number of seedlings that are produced after fire. This fire burned most of the stand at high intensity although some pockets of individuals survived (Fig 5). One year after fire, we counted 1019 seedlings in a 1/10th acre in one of our plots at Independence (Fig 6). In all other plots, we never counted more than 5 seedlings within a plot and this includes individuals that although they fit the definition of a seedling and were often less than 1 ft. in height, appear more similar in morphology to the older trees.


Figures 5 & 6. Independence Valley one year after fire. First year seedling.

Location	Last Fire	Average Tree Age	Average Cones/ Tree	% closed Cones	Average DBH(“)	Average Height (‘)	# seeds / cone	%viab
Seiad	1987/1951	65 ± 6	50-100	67	6.6 ± 0.3	30 ± 2	54 ± 1	6 ± 2
Independence	2006/1987	59 ± 10	250-500	n/a	7.0 ± 0.3	32 ± 2	n/a	n/a
Huckleberry Mtn.	1987	72 ± 4	50-100	74	8.8 ± 0.9	35 ± 3	57 ± 2	14 ± 2
Goosenest Mtn.	unknown	93 ± 6	500-1000	57	6.8 ± 0.3	29 ± 1	56 ± 2	18 ± 2
Mud Lake / Wheeler Pk	2007	113 ± 9	100-250	80	9.6 ± 0.5	39 ± 2	41 ± 2	19 ± 5
Hat Creek / Burney	unknown	45 ± 4	100-250	67	8.8 ± 0.9	34 ± 1	40 ± 1	15 ± 2
Timbered Crater	2000/1910	78 ± 3	250-500	40	6.2 ± 0.3	25 ± 1	63 ± 1	16 ± 3

Figure 7. Results of pre-treatment data collection

Plot Name	Last Fire	# Baker cypress trees (1/5 acre)	# Baker cypress saplings (1/10 acre) (<4" DBH)	# Baker cypress seedlings (1/10 acre) (<3.5' ht)
Seiad1	1987	25	20	1
Seiad2	unknown	10	0	0
Seiad4	unknown	45	9	0
Seiad5	1950	9	905	116
Indep3	2006	61	11	1019

Figure 4. Results of pre-treatment data collection

Core and cross-section samples ranged in age from 13 to 167 years. The average age at all locations sampled (not including sapling data) was greater than 45 years (Fig 7). Mud Lake contained the largest number of trees over 100 years of age. One plot at Goosenest mountain also contained a large number of older trees with all 8 trees sampled over 118 years. Most of the plots contained a few older trees mixed among a fairly even age stand across the rest of the plot. Tree DBH did not necessarily correspond to tree age. For example, one "seedling" from Huckleberry was 45 years old but was only 0.3" in diameter at it's base, while one 23.8" tree from Lassen was only 35 years old.

Cone estimated per tree ranged from zero to10,000 cones per tree. Number of cones per trees varied both by location and by tree size. While there was a direct correlation between tree size and number of cones ($r = 0.54463$, $p < .0001$, power = .999), differences based on location were also observed. Trees at Goosenest had the highest number of cones with and average of 500-1000 cones per tree. The largest trees at this site were estimated to have over 10,000 cones. The lowest number of cones per tree were observed at Huckleberry and Seiad where the trees on average had 50 –100 cones per tree. Trees in higher density stands produced fewer cones than those more open stands. The percent of closed cones on the trees also showed some variation per location. Overall, Goosenest had the lowest number of closed cones per tree. Mud Lake had the highest at 80% closed.

The average number of seeds per cone ranged between 39 and 63 seeds. The highest number of seeds were found in cones from Timbered Crater. This number may be spewhat skewed due to a few cones collected at this site that had over 100 seeds per cone. Hat Creek and Mud Lake had the fewest number of seeds on average. Our testing of seed viability indicated an overall seed viability of about 15%. Seeds collected from Timbered Crater and Hat Creek had the highest percent of viable seeds while Seiad had the fewest. These numbers reflect only cones that were completely closed when collected. Most of the non-viable seeds we dessicated upon dissection.

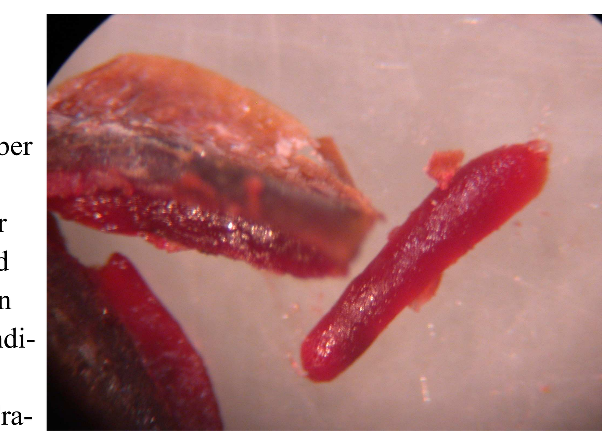

Figure 8. Seed treated with tetrazolium will stain red when tissues are active indicating a viable seed.

Figure 9. 3.1" DBH cross-section from Independence represent 100 years. An addition fire scar indicates a fire 40 years before 1987 fire.

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