Restoring fire to endemic cypress populations in northern California

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Abstract

Baker cypress (*Hesperocyparis bakeri*) and Macnab cypress (*Hesperocyparis macnabiana)* are rare fire-adapted conifers endemic to California and southern Oregon. These species bear closed (serotinous) cones that depend on fire for seed dispersal and require post-fire conditions, such as bare mineral soil and direct sunlight, to germinate (Vogl *et al.* 1977). Fire has been successfully excluded from many Baker and Macnab cypress populations for almost a century. Cypress groves at many sites are densely crowded with shade-tolerant species and adult cypresses are dying with almost no evidence of regeneration. The intent of our research was to provide land managers with critical information to manage cypress populations by determining if fire management is necessary to restore cypress populations, and if prescribed burning can successfully promote cypress regeneration. We also investigated factors that affect cypress vigor and canopy seed storage. We collected information on stand density, age, health, cone production, shrub and understory species cover, fuel loading, and environmental conditions at most of the known populations of Baker cypress (11 sites) and at three sites supporting Macnab cypress. We calculated canopy seed storage of Baker cypress at ten sites by collecting data on seed number, cone number, cone opening, and seed viability. We found almost no evidence of regeneration in cypress populations that had not recently burned. Populations must burn before adult trees die to regenerate. Low severity fire does not promote cypress regeneration, suggesting that typical prescribed burns may not effectively restore cypress populations. For Baker cypress we found evidence of immaturity but not senescence risk. Young stands do not have sufficient canopy seed storage to regenerate the population, but even very old stands of over 150 years of age still possessed very high numbers of viable seed. Baker cypress canopy seed storage was most strongly influenced by site conditions, particularly soil type; however, stand density and the height of the cypress relative to other species were also strong predictors of canopy seed storage. This suggests that management measures such as selective thinning could be used to promote canopy seed storage of Baker cypress populations.

II. Background and Purpose

Ten species of cypress are native to California, eight 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 grow 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 (*Hesperocyparis bakeri)* occurs in 11 widely scattered locations 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 3,795 to 7,042 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.

Macnab cypress (*Hesperocyparis macnabiana)* is one of the more widespread cypress species in California. It is found at approximately 30 sites in 12 counties across California (Vogl et al. 1977). Macnab cypress occurs on dry slopes, exposed hillsides, and ridge tops at elevations from 1,000 to 2,800 feet. The species is often associated with serpentine soils and is considered a serpentine indicator (Kruckeberg 1985; Esser 1994). Macnab cypress also occurs on clay, alluvial, granitic, and volcanic soils and is associated with chaparral, knobcone pine, mixed evergreen, and montane coniferous forest community types (Esser 1994).

The USDA Forest Service is currently implementing fuels treatments, including prescribed burning, across a range of vegetation types in northern California; however, there is very little information about how these treatments will affect rare, endemic plant communities and species such as Baker and Macnab cypress. In many cases cypress stands have not been included in prescribed burning programs because of lack of information, yet these species cannot survive extended periods of fire suppression. Baker and Macnab cypress possess closed or serotinous cones that open in response to fire, and seeds that require high light and exposed mineral soil characteristic of burned areas to germinate (Vogl *et al.* 1977). Adult cypress are often killed by fire and land managers risk extirpating cypress occurrences by conducting prescribed burning programs that do not adequately promote cypress regeneration.

In order to effectively manage cypress populations, land managers need information about factors that promote cypress regeneration and affect cypress vigor. The objectives of this study were to provide critical information for cypress management by determining if fire is necessary to restore cypress populations, and what intensity and fire return intervals promote cypress regeneration. We also investigated factors that affect Baker cypress canopy seed storage.

1. Is fire necessary to maintain cypress populations?

Many cypress species grow in even-aged stands, suggesting that populations germinate in single cohorts after stand-replacing fires (Ne'eman et al. 1999). Although a few cypress cones may open in the absence of fire, cypress seeds are thought to quickly lose viability when outside of the cone (Johnson 1974; Vogl *et al.* 1977). Observations of Baker cypress seedlings along roadsides and in other disturbed areas such as stream beds suggest this species can regenerate in the absence of fire (Fig. 1).

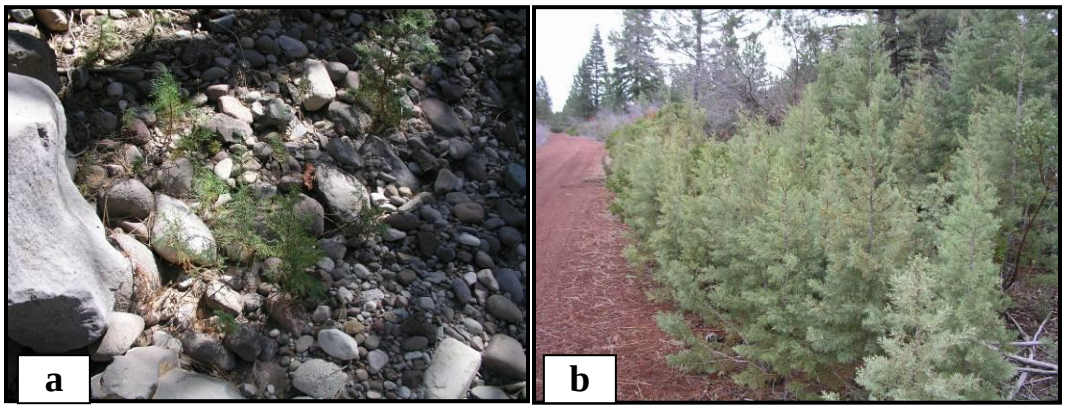

Fig 1. Baker cypress saplings and seedlings in a dry river bed (a) and along a roadside (b).

2. **Can prescribed burning sucessfully promote cypress regeneration? What fire intensity and return interval is appropriate for cypress management?**

Under natural fire regimes, cypress stands were likely subject to high intensity crown fires (Vogl *et al.* 1977). Cypress retain numerous dead lower branches and often grow in dense thickets, which are conducive to crown fires. High severity fire produces favorable conditions for cypress germination and seedling survival, such as high light and bare mineral soil (Vogl *et al.* 1977). Most species of cypress are poor competitors, and seedling survival is highest on sites where competition is reduced (Ne'eman *et al.* 1999). Post-fire recruitment might depend on high fire intensity to reduce competition by killing the dormant seeds of other species (Keeley and Zedler 1988). It is not known if a prescribed burn, generally carried out at low intensity and resulting in low fire severity, can create the kind of conditions necessary for cypress recruitment and survival.

Cypress species lack the ability to resprout and it is believed that cypress seeds have very limited dormancy once they are dispersed from the cone. The primary seed source for post-fire regeneration comes from seeds accumulated inside cones (Vogl *et al.* 1977; Ne'eman *et al.* 1999). Fire return interval largely determines the size of the canopy seed bank for these fire dependent obligate seeding species (Ne'eman et al. 1999). If fires occur too frequently, cypress may not have sufficient seeds to regenerate the population and are subject to “immaturity risk” (Keeley et al. 2000(Ne'eman *et al.* 1999)). On the other hand, if the fire return interval is longer than the life span of the cypress or its seed bank, these individuals may face a “senescence risk” (Fig. 2).

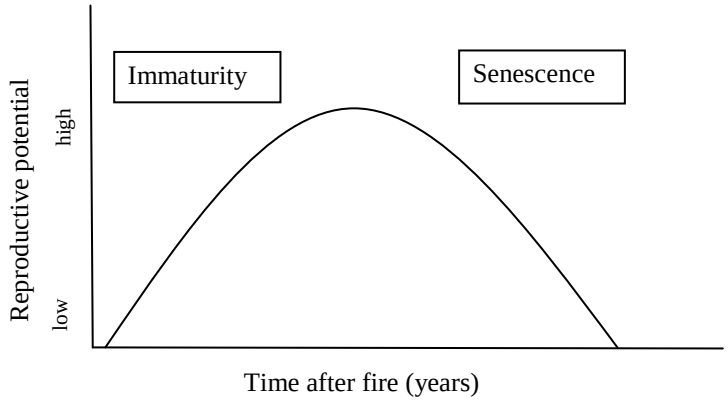

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Figure 2. Risks associated with fire dependent obligate seed regeneration. Modified from Keeley and Fotheringham (2000).

Both Macnab and Baker cypress do not begin producing ovulate cones until the trees are at least 14 years of age or older and these cones require two years to mature (Armstrong 1966). Because many cypress species have low germination rates, the number of seeds required to replace an entire stand is likely quite high. Zedler (1977) found that Tecate cypress (*C. forbesii*) required several decades to generate sufficient canopy seed storage in cones for successful post-fire regeneration of the stand. He concluded that this species is extremely vulnerable to extirpation when fires occur more than once every 30 years.

There is evidence that as cypress stands age recruitment declines, perhaps as a result of decreased seed viability in older cones. (Zedler 1977; Zedler 1995; Ne'eman *et al.* 1999). Many Baker cypress stands have gone almost a century without fire, and mature adult cypress are dying at some sites with no sign of regeneration (Wolf 1948; Wagener and Quick 1963; Vogl *et al.* 1977; Keeler-Wolf 1985). However, no studies have quantified canopy seed storage of Baker or Mcnab cypress or examined the effect of stand age on seed production.

3. What factors affect cypress vigor, and can management actions be taken to promote canopy seed storage of existing cypress populations?

There is evidence that interspecific competition can negatively affect cypress (Keeler-Wolf 1984). However, information about how competition or other variables such as soil type, shrub cover, or fuel loading affects canopy seed storage is lacking. Understanding conditions that promote cypress canopy seed storage will allow for the development of management actions to promote cypress vigor before fire management efforts occur.

III. Study description and locations

Data on Baker cypress were collected from eight sites in Northern California on the Klamath, Lassen, and Plumas National Forests. One site is located on lands administered by the Bureau of Land Management (BLM) Alturas Resource District. Two sites are located in Southern Oregon, one within the BLM Butte Falls Resource Area and one on the Rogue River-Siskiyou National Forest (Fig. 3). Descriptions of each study site are shown in Table 1.

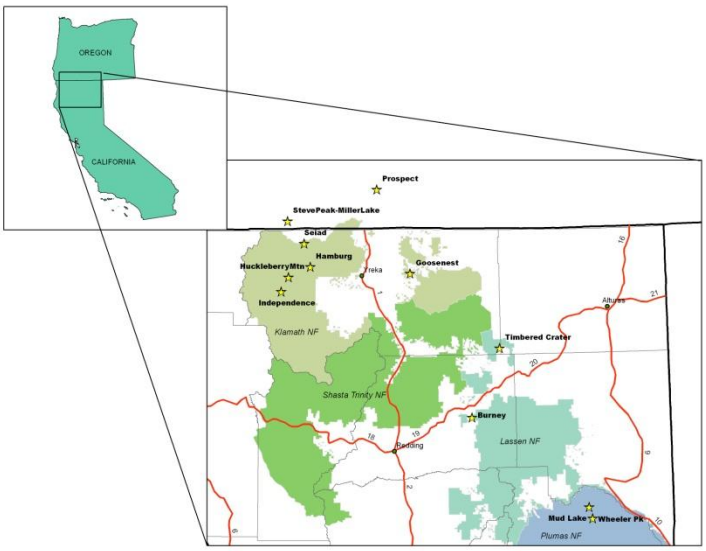

Figure 3. Distribution of Baker cypress in northern California and southern Oregon.

Table 1. Characteristics of Baker cypress study sites.

Location	National Forest	Estimated Size (acres)	Elevation	Soil Type	Last Fire	Avg. Tree Age ± SE
Seiad	Klamath	800	3,000-3,800	ultramafic	1987/1951	68 ± 5
Independence	Klamath	< 5	4,800	granitic	2006/1987	60 ± 9
Huckleberry Mtn.	Klamath	55	3,800-4,600	ultramafic	1987	72 ± 4
Goosenest Mtn.	Klamath	300	5,000-6,000	volcanic	unknown	98 ± 7
Hamburg	Klamath	16	4,400-5,200	ultramafic	unknown	149 ± 6
Mud Lake	Plumas	307	6,400-6,900	volcanic	2007	135 ± 5
Wheeler Peak	Plumas	73	6,400-6,900	volcanic	unknown	95 ± 6
Hat Creek / Burney	Lassen	1500	4,500-5,000	volcanic	1936	56 ± 6
Timbered Crater	Lassen/BLM	7,000	3,500-4,000	volcanic	2000/1910	70 ± 4
Flounce Rock-Prospect, OR	BLM	< 3	4,000	metasedimentary	unknown	132
Steve Peak, OR	Rogue/ Siskiyou	< 50	4,000-5,200	metasedimentary	unknown	No Data

Data on Macnab cypress were collected from three sites on the Plumas National Forest in Butte County, California (Fig. 4). Descriptions of each site are provided in Table 2.

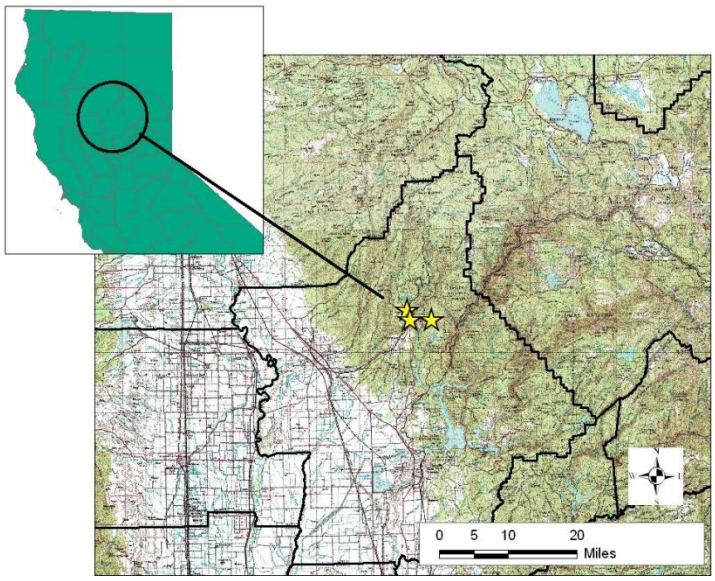

Figure 4. Macnab cypress sites, Butte County, California.

Table 2. Characteristics of Macnab cypress sites.

Location	National Forest	Estimated Size (acres)	Elevation (ft)	Soil Type	Avg. Age ± SE	Date of Last Fire
Hollywood	Plumas	11	2200	Ultramafic	35 ± 4	unknown
Coutolenc	Plumas	15	2300	Ultramafic	77 ± 7	unknown
Concow	Plumas	95	2520	Ultramafic	164 ± 11	2008/1966

At each site one to ten random plots were established depending on the size of the cypress stand. We recorded the species, diameter, height, and crown condition class for all trees with a diameter at breast height (DBH) greater than four inches. To estimate seedling and sapling densities, we recorded: a) the species and diameter class for all saplings taller than 4.5 feet; and b) the species and height class for all seedlings under 4.5 feet tall, within smaller nested subplots.

To estimate tree age we collected cores from six individual trees in each plot, representing the entire range of size classes present. We also estimated the number of cones per tree as well as the percentage of closed cones. For Baker cypress, we collected a branch from each of these six trees and selected ten cones which were placed in individual paper bags for processing in the lab. We counted the number of fully developed and underdeveloped seeds

present in each cone and recorded whether the cone 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). We calculated seed storage as the number of viable seeds stored in closed cones per tree (canopy seed storage = # of seeds/cone **x** % viability **x** # of cones/tree **x** % closed cones/tree). We also calculated seed storage at the plot level by multiplying the average canopy seed storage of the six individual trees by the number of trees per plot.

Vegetation cover was measured using 1-meter square (m^2) quadrat frames placed at standard locations along transects radiating from plot center. Within each 1-m^2 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), and live tree bole. Cypress seedling density was also recorded within the 1-m^2 quadrat frame. We measured canopy closure at each 1-m^2 frame location using a spherical densiometer. In addition to vegetation data, we measured fuel loading according to Brown (1974).

At sites recently burned by wildfire, we collected additional data on fire severity including scorch height, bole char height, and percent crown scorch of all trees. We also estimated fire severity according to a categorical scale, which included soil and vegetation factors (USDI National Park Service 2003). Regeneration was measured as the number of cypress seedlings present within the 1-m^2 quadrat frames.

IV. Key Findings

1. Cypress seedlings are found primarily after wildfires.

Across all study sites we found less than 100 Baker cypress seedlings in areas that had not experienced a recent fire. Core data revealed that many small trees, considered seedlings because they were less than 4.5 ft high, were up to 40 years of age. When we evaluated only those seedlings that germinated in the last five years, fewer than 5 seedlings were found in most of the plots sampled. Only stands with recent fire history contained a high number of new progeny, with the exception of one plot at the Lassen site which contained 18 seedlings. This plot was in an area that had been recently cleared and the soil was highly disturbed. Although ground disturbances may allow some cypress seeds from opened cones to germinate, the seedling densities we measured in this disturbed area were very low, averaging 5 seedlings/m^2, compared with up to 85 seedlings/m^2 observed at sites after fires.

Macnab cypress also exhibited very low regeneration and high seedling mortality rates at sites without recent fire. Of 11 Macnab seedlings found in plots at an unburned site in 2006, none were observed in 2007. In contrast, Macnab seedling densities in high severity plots at a recently burned site averaged 16 seedlings/m^2.

These data confirm that fire is critical to regeneration of both Baker and Macnab cypress stands. Seedlings in unburned areas are uncommon; however, recently burned sites can

support up to 85 seedlings per square meter. Post-fire cone opening appears to release larger numbers of seeds and result in higher rates of germination (Wolf 1948; Zedler 1986) (Fig. 5).

Figure 5. Baker cypress regeneration after the 2007 Moonlight Fire on the Plumas National Forest.

We found that some Baker and Macnab cypress populations were characterized by uneven aged stands (Fig. 6).

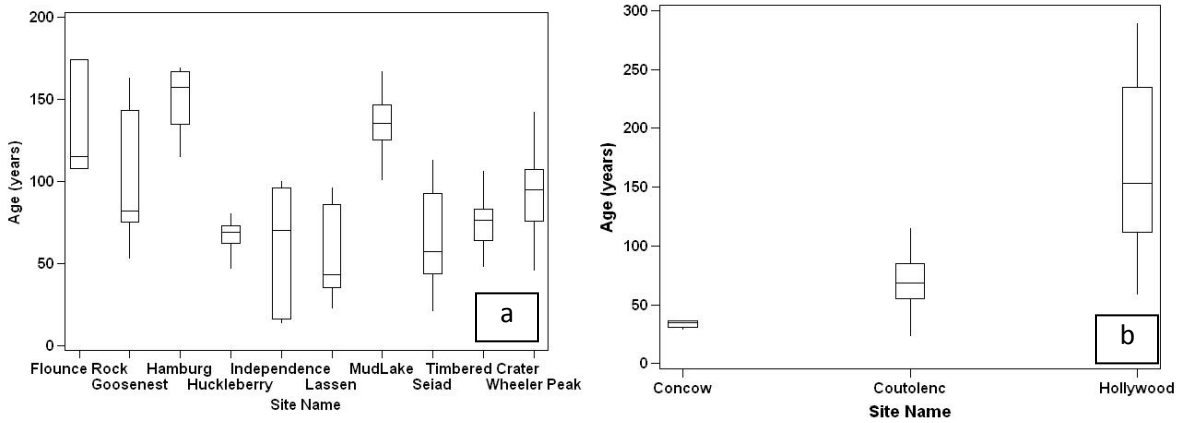

Figure 6. Box and whisker plot of tree ages at each Baker cypress (a) and Macnab cypress (b) population sampled.

Stand age variation within Baker cypress populations was largely related to the fire history of each site. Sites that had experienced multiple fires exhibited a wide range of age classes. Portions of the Independence Baker cypress population burned in both 1987 and 2006, and cypress trees within this population ranged in age from 16 to 96 years. Portions of the Seiad Baker cypress population burned in 1950 and 1987. Trees at this site ranged from 21 to 113 years of age. On the other hand, sites that had experienced a large, single fire were often characterized by even aged stands. For example, the Macnab cypress population at the Concow site experienced a fire in 1966 and most trees at this site aged between 29-36 years.

Heterogeneous fire effects may also have produced uneven aged cypress stands. The wildfires we observed in both Macnab and Baker cypress populations burned only portions of the site. The 2008 Concow Fire killed some Macnab cypress trees at the Concow site, but many others were still alive after the fire (Fig. 7a). The Moonlight Fire burned with a range of intensities through the Baker cypress population at the Mud Lake site, causing high mortality rates in some areas, but leaving other portions of the population unburned (Fig. 7b).

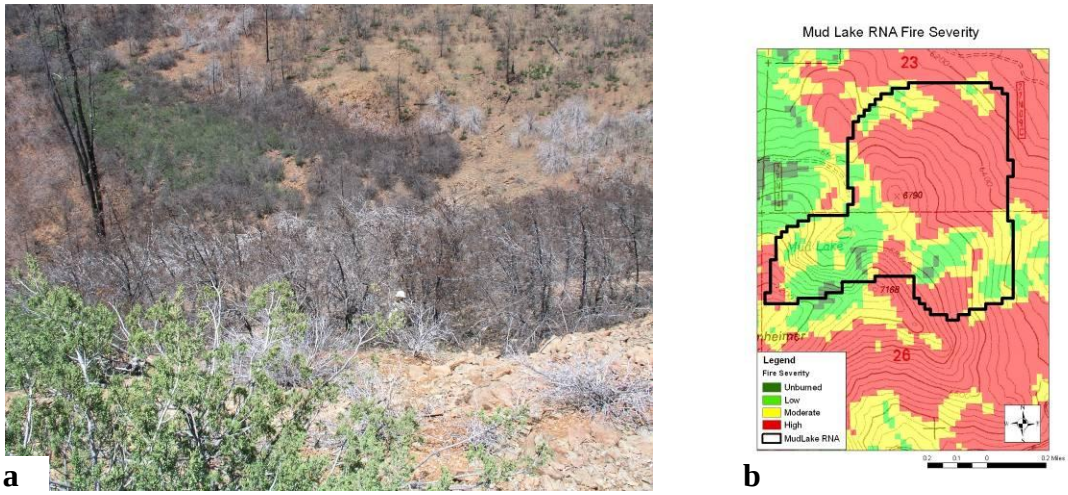

Figure 7. Photo showing variation in fire effects to Macnab cypress after 2008 Concow Fire (a), and variation in fire severity in a Baker cypress stand (shown in black) after the 2007 Moonlight Fire. Low severity (<25% basal area mortality) shown in green (b).

Topography is also an important factor influencing fire history and tree age distribution within cypress stands. Baker cypress populations growing in areas with a complex topographical structure had greater age variation than populations growing in more continuous topography. For example, the west side of Goosenest Mt. is a series of densely vegetated islands separated by large areas of exposed lava (Fig. 8). Lava flows act as a natural barrier to fire, limiting spread from island to island and resulting in large variation in age among stands.

Figure 8. Baker cypress at Goosenest Mountain where stands are separated by lava flows.

Other Baker cypress stands were found on rocky outcrops, isolated from the rest of the population. The oldest trees were typically found in these areas, such as at the Wheeler Peak site (Fig. 9a). Similarly, the oldest Macnab cypress tree at the Hollywood site was also found on an isolated rock outcrop (Fig. 9b). These outcrops may act as refugia for trees allowing some to survive high severity fires.

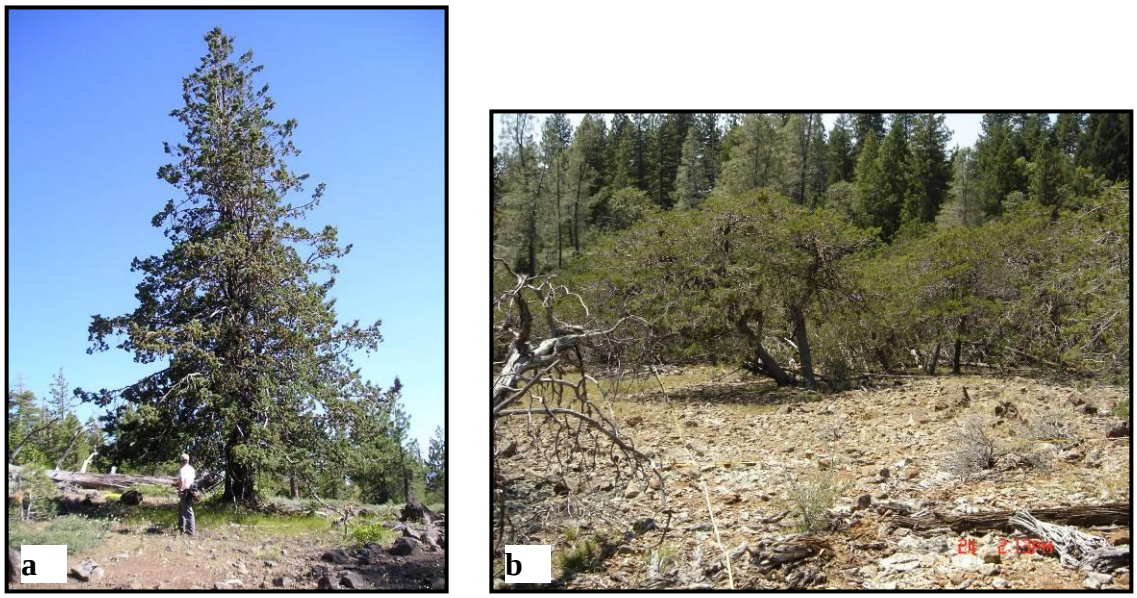

Figure 9. 140 year-old Baker cypress at the Wheeler Peak site (a) and 289 year-old Macnab cypress at the Hollywood site (b) isolated by rocky outcrops.

2. *High severity fire promotes cypress regeneration*.

Fire severity significantly affected both Macnab and Baker cypress regeneration rates. After the 2007 Moonlight Fire, Baker cypress in plots with higher scorch and char heights and more severe soil fire effects had significantly higher densities of seedlings (Fig. 10a). Similarly, after the 2008 Concow fire Macnab cypress seedling density increased with higher amounts of crown consumption and crown scorch (Fig. 10b). This is likely because the serotinous cones of both cypress species require heat to open and to release seeds. High fire severity may promote cypress germination by exposing more mineral soil, increasing light availability, and reducing competition.

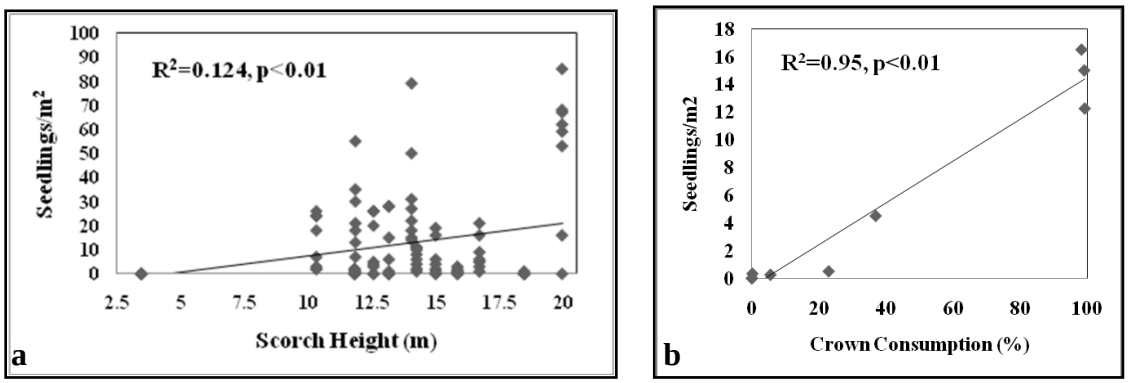

Figure 10. Scorch height and Baker cypress regeneration after the 2007 Moonlight Fire (a); and crown consumption and Macnab cypress regeneration after the 2008 Concow fire (b).

3. *Cone production and seed storage do not decline with tree age.*

We found no evidence of reduced cone production with age for either species of cypress (Fig. 11a, b). Macnab cypress cone production increased linearly with age. Baker cypress cone production was significantly lower in trees less than 50 years old, but remained constant across older age classes. These data provide evidence of immaturity, but not senescence, risk among these populations.

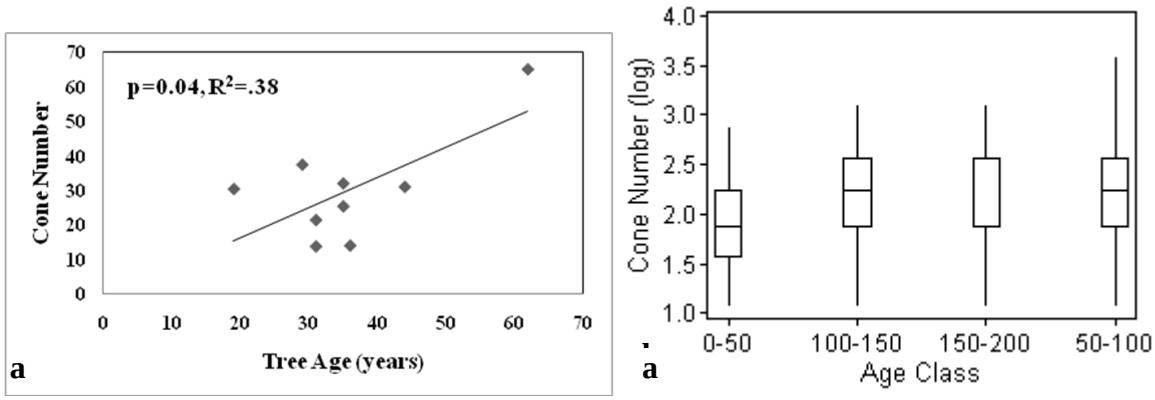

Figure 11. Tree age and cone production of Macnab cypress (a) and Baker cypress (b).

Contrary to expectation, we did not observe a significant decline in Baker cypress canopy seed storage with age, even in Baker cypress trees that were over 150 years old (Fig. 12).

Baker cypress trees younger than 16 years of age did not possess cones, indicating that immaturity is a risk for very young stands of cypress.

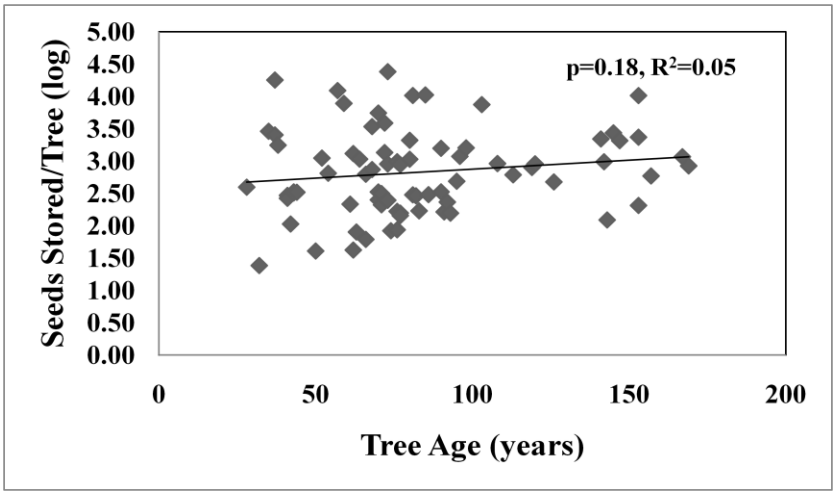

Figure 12. Relationship between canopy seed storage and age of Baker cypress trees.

4. Baker cypress seed storage is influenced by site factors and competition.

We evaluated the effect of a number of variables, including fuel loading, slope, aspect, elevation, ground cover, understory and shrub cover, tree density, and soil type on canopy seed storage of Baker cypress. The total number of viable seeds stored by Baker cypress trees was most strongly related to soil type. Baker cypress growing on volcanic soils had much higher numbers of viable seeds than stands growing on peridotite soils at both the individual tree and plot level (Fig. 13). Peridotite soils are nutrient poor, which may reduce Baker cypress canopy seed storage.

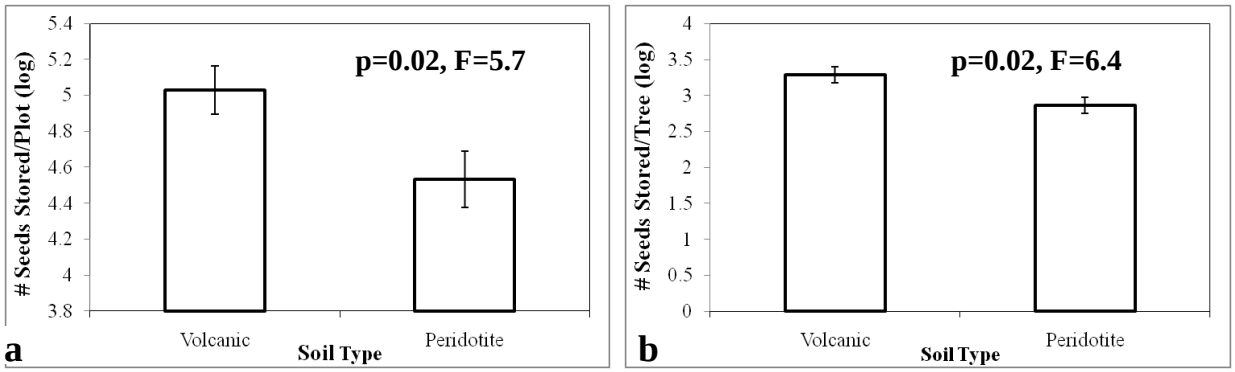

Figure 13. Effect of soil type on seed storage per tree (a) and per plot (b).

Although soil type had strong effect on Baker cypress seed storage at both the tree and plot level, several other factors were also important. For individual Baker cypress trees the following factors influenced canopy seed storage:

- *Elevation.* Baker cypress stands located at higher elevations had greater canopy seed storage.
- *Relative Height.* As the height of competitor tree species increased relative to the height of the Baker cypress seed storage decreased (Fig. 14a).
- *Stand density.* Seed storage of individual cypress trees decreased as total stand density increased (Fig. 14b).
- *Shrub cover.* Seed storage of individual cypress trees decreased as shrub cover increased (14c).

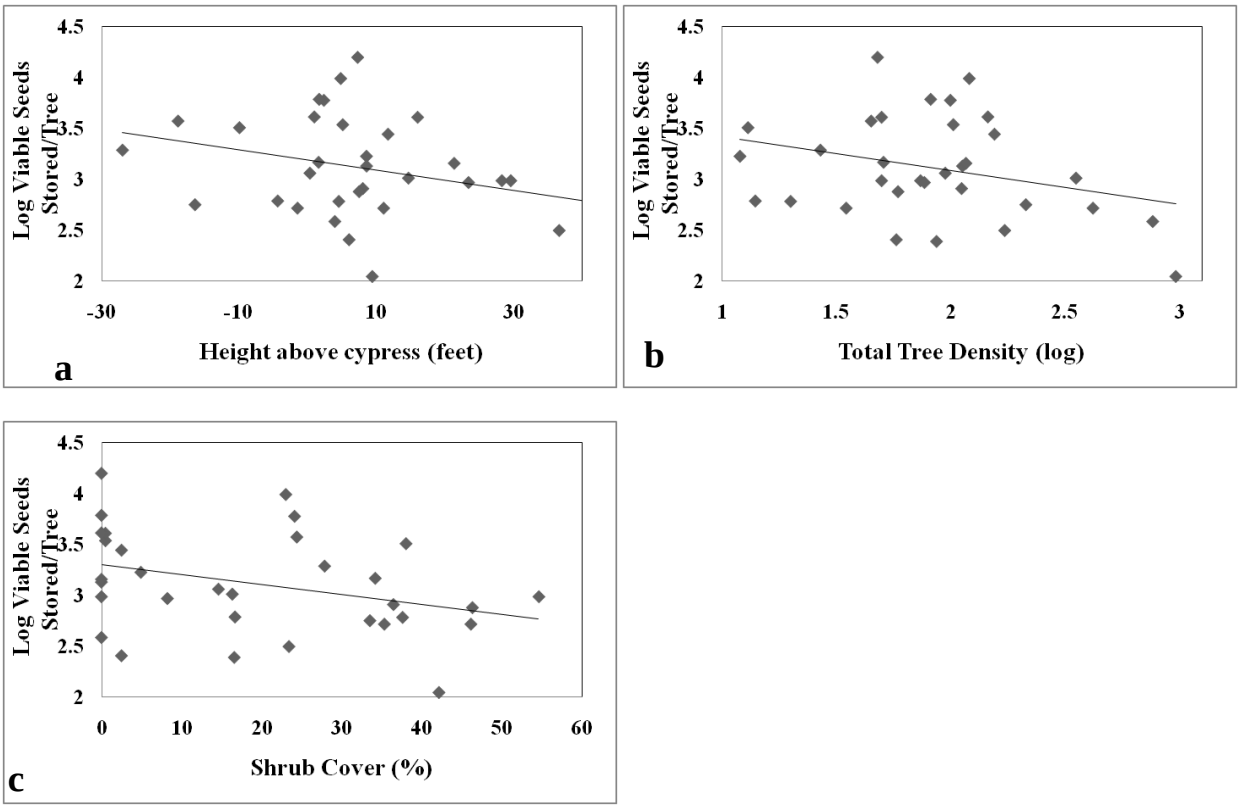

Figure 14. General linear modeling showed that after the effect of soil type, the height of other trees above the cypress (a), total stand density (b), and shrub cover (c) had the strongest effect on canopy seed storage of individual trees (R2= 0.4, p<0.01).

At the plot level, a general linear model found that in addition to soil type, the height of other species above Baker cypress trees had a significant effect on plot-level canopy seed storage. As other tree species grew taller than Baker cypress, plot-level canopy seed storage declined.

Macnab cypress. We did not collect data to calculate canopy seed storage for Macnab cypress; however, our analysis of cone number and crown condition demonstrated that Macnab cypresses at the three sites we studied were not negatively affected by stand density or shrub cover. This suggests that competition did not negatively affect Macnab cypress vigor at these three sites.

V. Management Implications

1. Cypress stands must burn before adult trees die to regenerate populations.

We found that fire is required for both Baker and Macnab cypress to successfully regenerate. A policy of fire suppression is not appropriate for cypress populations unless they are very young. In order to ensure the persistence of cypress populations, it is important to return fire to the stands, at appropriate fire return intervals, either through wildfires or through prescribed burning. Our observations of wildfires and stand age distribution among cypress populations suggest that although fire is likely the predominant determinant of stand age among Baker and Macnab cypress, many fires burn heterogeneously through cypress populations. As a result, many populations of Baker and Macnab cypress are characterized by uneven aged stands. This is most likely a result of varied topography and fuel discontinuity. Prescribed burning of cypress does not necessarily need to include the entire stand at once. Burning only a portion of a stand may allow managers to use an experimental approach to develop prescriptions for fire management of cypress populations.

2. High severity fire promotes cypress regeneration.

Our results suggest that a low severity prescribed fire would likely not effectively promote either Macnab or Baker cypress regeneration. Fire intensity should be high, including scorching and/or consuming the entire crown and exposing bare mineral soil. Reintroducing high severity fire into cypress stands, either through unconventional prescribed burning approaches or by allowing wildfires to burn, will likely be necessary to promote sufficient regeneration to restore cypress populations.

3. Immaturity, but not senescence, is a risk for cypress.

We found that immaturity is a risk for Baker and Macnab cypress populations that have not accumulated sufficient seeds to regenerate the population after a fire; however, we found no evidence of senescence risk to either cypress species. Cone production increased with age in both Baker and Macnab cypress. Canopy seed storage increased with age in Baker cypress. Baker cypress had a significant increase in canopy seed storage in populations over 50 years of age. This suggests that minimum fire return intervals of 35-50 years would be appropriate for these stands. These fire return intervals are typical of mixed fir forests where many Baker cypress populations are found.

Senescence does not threaten Baker cypress populations. We found that even older stands of Baker cypress continued to store large numbers of viable seed. Tree age may not determine appropriate maximum fire return intervals. We found that other factors, described below, had a much stronger influence on canopy seed storage than stand age.

4. Reducing competition may benefit Baker cypress by promoting seed storage, but may not be important to Macnab cypress crown condition or cone

production. Management measures such as thinning may benefit Baker cypress populations.

Our data show that soil type had the strongest influence on Baker cypress canopy seed storage; however, stand density, relative height, and shrub cover also affected seed storage at the individual tree and plot level. This suggests that management actions such as selective thinning, particularly of taller interspecific trees, may promote canopy seed storage of Baker cypress populations.

Although we did not calculate canopy seed storage for Macnab cypress, cone production and crown condition was not related to stand density, shrub cover, or tree height. This suggests management actions such as selective thinning may not improve Macnab cypress vigor; however, more information is needed. Landscape scale factors such as soil type may also influence Macnab cypress populations, but with only three populations we did not have a sufficient sample size to evaluate these variables.

Lassen Baker Cypress Population

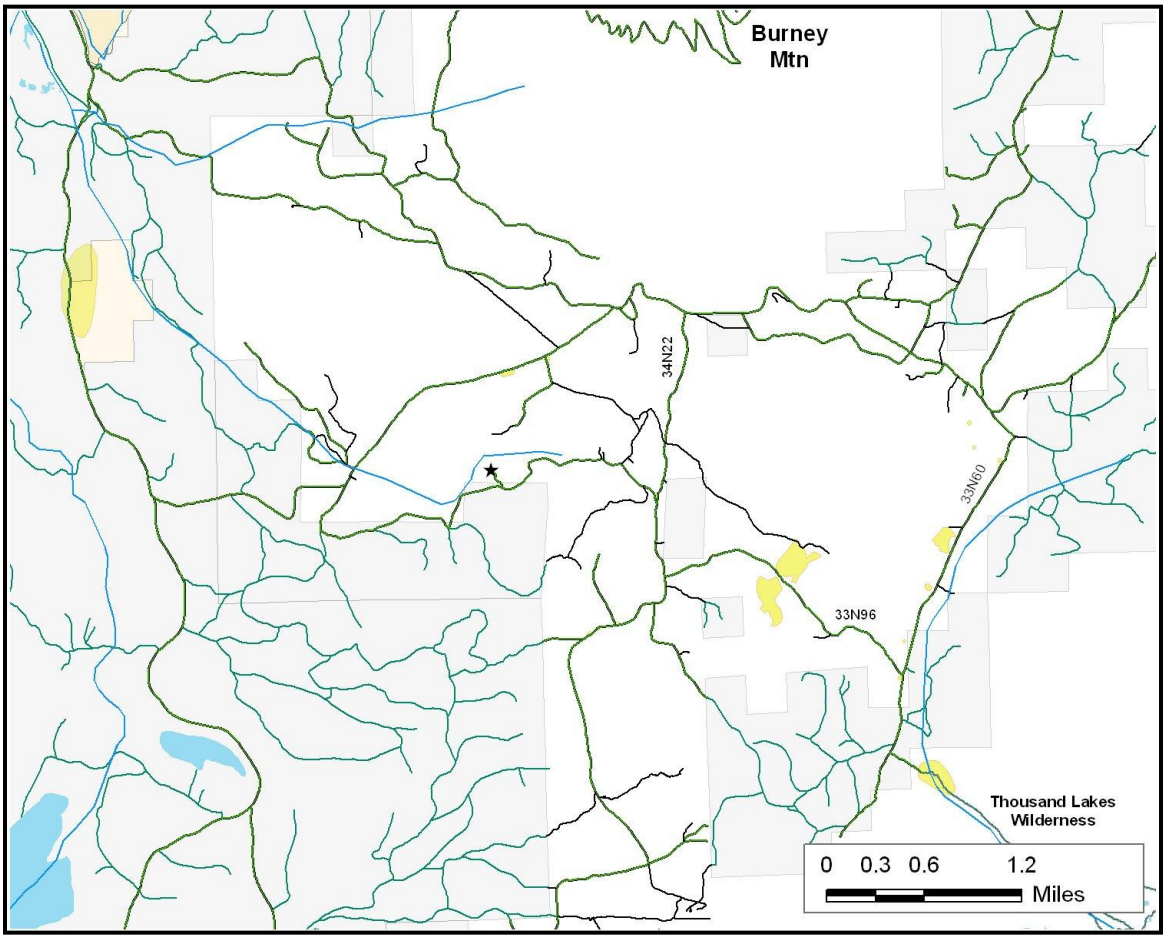

Figure 15. Map of Baker cypress population at the Lassen site.

General Description

The population of Baker cypress at the Lassen site is widely scattered across 10 square miles south of Burney Mountain. It is located approximately 8 miles south of the town of Burney in Shasta County, California (Fig. 15).

Legal: T34N, R3E, Sections 26, 27, 34, and 35.

UTM at center point: NAD83, Zone 10, Easting (X) 617331, Northing (Y) 4514299.

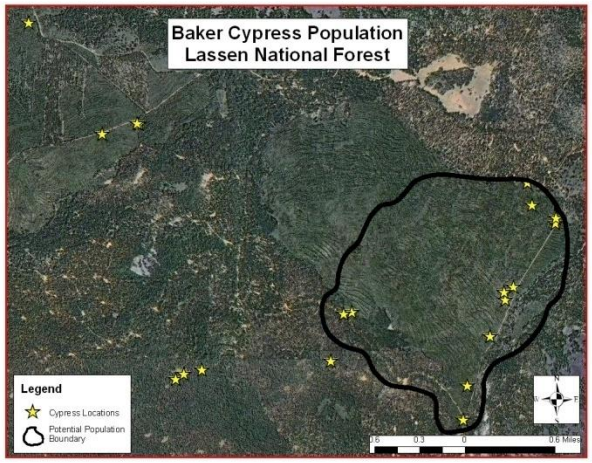

Figure 16. Map of Baker cypress stands at the Lassen site.

Elevation: 4500-5000 ft, on slopes of 0-15%, with a north to northeastern aspect.

The Baker cypress population at the Lassen site includes three widely disjunct stands in the western portion of the population, and a cluster of stands in a large pine plantation in the southeastern area of the population (Fig 16). The 1300-acre plantation area may support a large, contiguous Baker cypress stand; however, this area has not been thoroughly surveyed due to inaccessibility from dense brush.

Soil type – Volcanic

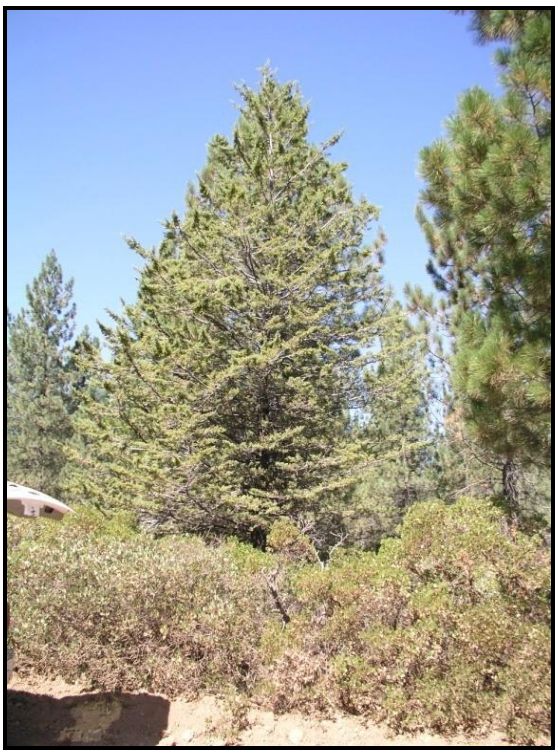

Figure 17. Large Baker cypress growing along roadside at the Lassen site.

Baker cypress at the Lassen site occurs in monotypic stands along windrows within the plantation area; as single large trees in open areas along roadsides (Fig. 17) or in the middle of chaparral patches; and as a minor component of the adjacent mixed conifer forest. Common associated species include Jeffrey pine (*Pinus jeffreyi*), snowbrush (*Ceanothus velutinous*), greenleaf manzanita (*Arctostaphylus patula*), and bush chinquapin (*Chrysolepis sempervirens*).

There is no record of wildfire since 1910 in areas supporting Baker cypress at the Lassen site. Baker cypress trees as old as 98 years suggest that wildfire has been suppressed from this area for some time. Prescribed burning was conducted in 1936 when the plantation area was initially cleared and planted in ponderosa and Jeffrey pine. The plantation has been repeatedly cleared and replanted since then (Fig. 18).

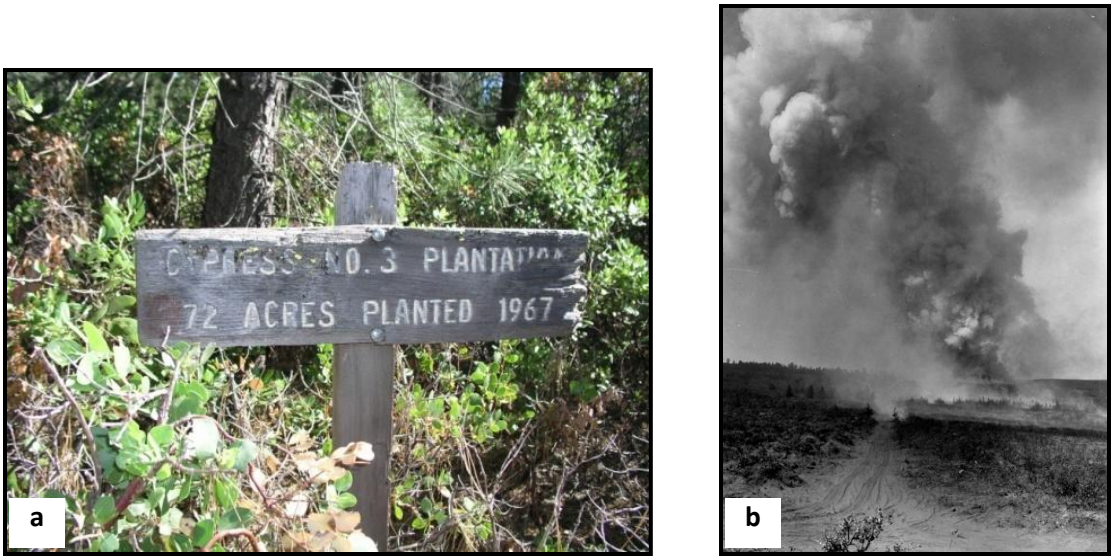

Figure 18. Sign documenting planting of 72 acres within the "Cypress plantation" in 1967 (a), and burning operations in 1936 when plantation was established (b).

Existing conditions in the stand

The average age of Baker cypress trees cored at the Lassen site was 56 years. This is the youngest population of Baker cypress across the range of the species, not including sites that have recently burned. Individual trees varied greatly in age, ranging from 2 to 96 years old. The oldest trees were near roadsides and on rocky outcrops and may be remnants of older populations, which were mostly eliminated by previous disturbances associated with the establishment and maintenance of the plantation.

Figure 19. Baker cypress saplings at the Lassen

We observed a relatively large number of Baker cypress seedlings and saplings within the Lassen population; we found 57 seedlings less than 1.6 ft tall in our plots (Fig. 19). This is unusual for a Baker cypress population that has not recently burned. The presence of seedlings could represent small scale regeneration associated with clearing and other disturbances at the Lassen site; however, seedling densities within the Lassen population were very low compared to densities observed at sites with recent fires.

Fig. 20. Cypress covered with mistletoe.

Baker cypress at the Lassen site are vigorous compared to other populations. On average, 40 percent of Baker cypress owns at the Lassen site were dead or dying. Across the range of Baker cypress, crown condition averaged 44 percent dead or dying, ranging from 24 percent to 70 percent. Baker cypress trees were often covered with mistletoe and lichen at the Lassen site, but we do not know what effect, if any, this might have on cypress vigor (Fig. 20).

Baker cypress were overtopped by Jeffrey pine in several of our plots (Fig. 21). However, we calculated the average canopy seed storage of this site to be high compared with other populations of Baker cypress across the species range.

Some Baker cypress stands at the Lassen site occur on private land. A number of trees in these areas have been removed by logging and clearing activities (Fig. 22a). Other Baker cypress trees have been removed by woodcutters within the boundaries of the Lassen National Forest (LNF) (Fig. 22b).

Fig. 21. Baker cypress (CUBA) height compared to the height of Jeffrey pine (PIJE) at the Lassen site.

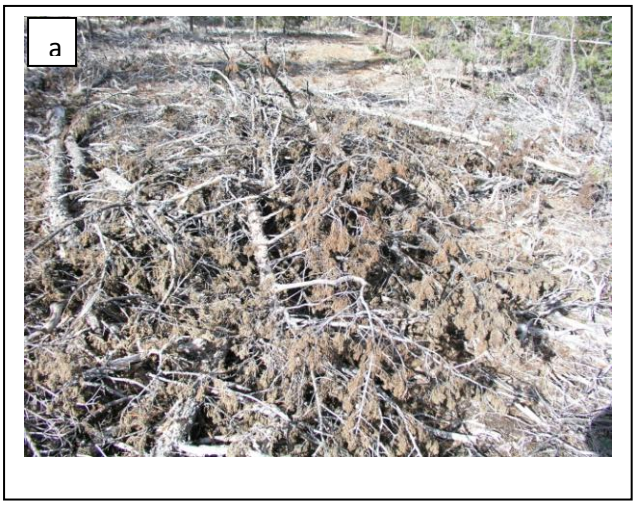

Figure 22. Baker cypress removed by logging on private land (a) and woodcutting on the LNF (b).

Current fire conditions

There have been no large wildfires recorded at the Lassen site since 1910, other than prescribed burning of the plantation area in 1936. Fuel loading at the Lassen site averaged 74 tons/acre. This was relatively low compared to other sites across the range of Baker cypress, where fuel loadings averaged 138 tons/acre, ranging from 46 to 627 tons/acre. Unlike some other populations across the species range, the Baker cypress population at the Lassen site does not appear to require fire management to prevent immediate extirpation. On the other hand, the Baker cypress population at the Lassen site has very high canopy seed storage, and would likely regenerate well should a high severity wildfire occur. Fire suppression is therefore not recommended around this population.

Some isolated Baker cypress individuals at the Lassen site are almost 100 years old and show signs of declining health. These individual trees may die before they can reproduce. Selective burning of these isolated individuals might promote regeneration, but only if the prescribed burn is at high intensity.

Management recommendations

- We recommend that surveys be conducted throughout the plantation area to better document the distribution of Baker cypress.
- Restricting cutting of cypress through LNF wood cutting permits and inclusion of informational materials about cypress, would help prevent inadvertent destruction of cypress by wood cutters.
- We recommend working with private landowners in the area to protect cypress stands.
- Baker cypress would benefit from selective thinning of Jeffrey pine, particularly in plots where they are taller than Baker cypress.
- We do not recommend that prescribed burning be conducted across the entire Baker cypress population.
- Fire suppression is not recommended because the Lassen Baker cypress population has high canopy seed storage, and should regenerate well after a high severity wildfire.
- High intensity prescribed burning of some isolated, older individuals might allow them to regenerate before they die.
- Finally, mastication is not recommended because the relatively large number of Baker cypress seedlings and saplings at the Lassen site might be inadvertently damaged by mastication activities.

Mud Lake and Wheeler Peak Baker Cypress Populations

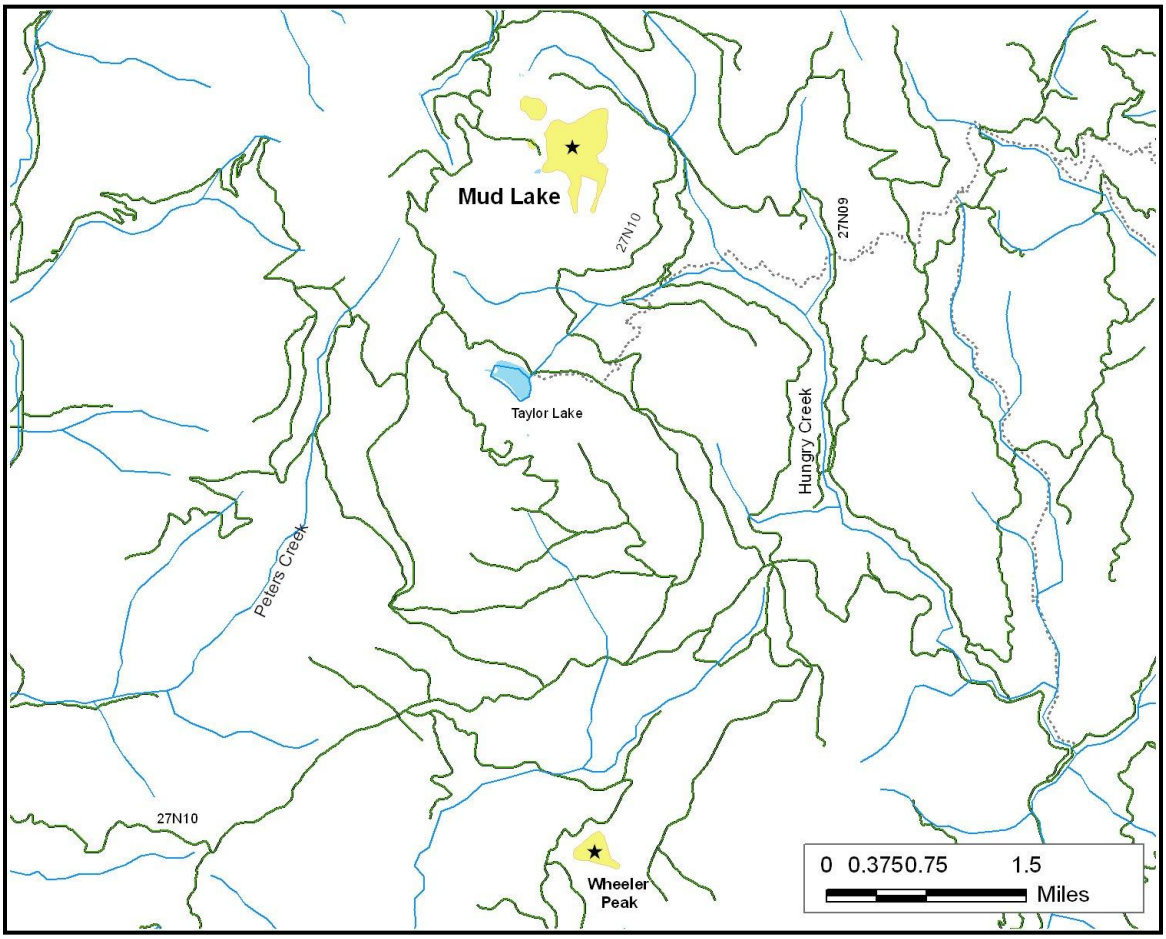

Figure 23. Map of Baker cypress populations at the Mud Lake and Wheeler Peak sites.

General Description

The Mud Lake Research Natural Area (MLRNA) on the Plumas National Forest contains two populations of Baker cypress separated by about 5 miles. The MLRNA is near the Diamond Mountains in the northern portion of the Sierra Nevada, about 13 miles east of Greenville in Plumas County, California (Fig. 23).

Legal: *Mud Lake*- T27N, R11E, Sections 23 and 26; *Wheeler Peak*- T26N, R11E, Section 23.

Fig. 24. Baker cypress trees and seedlings at the Mud Lake site.

UTM at center point: NAD83, Zone 10, *Mud Lake*: Easting (X) 701479, Northing (Y) 4442072;), *Wheeler Peak*: Easting (X) 695079, Northing (Y) 4440801.

Elevation: 6,000 to 7,300 feet, on slopes ranging from 0-30%, with a north to northeastern aspect**.**

The total acreage of the MLRNA is 380 acres. The Wheeler Peak site contains 73 acres and the Mud Lake site is 307 acres in size. Baker cypress stands are widely scattered throughout these two units of the MLRNA (Fig 24).

Soil type – Volcanic

The MLRNA was established in 1989 to preserve two isolated populations of Baker cypress in Plumas County (Fig 25). Baker cypress within the MLRNA represent the highest elevation, and furthest inland, occurrences of this species; no other cypress species in California has been documented above 6,000 feet in elevation and further than 150 miles inland from the Pacific Ocean (Keeler-Wolf 1989). The two populations of Baker cypress within the MLRNA are likely subjected to lower temperatures and more snowfall than any other population of cypress in California or the world (Peattie 1953).

Fig. 25. Large Baker cypress at the Wheeler Peak site.

The Mud Lake unit of the MLRNA burned during the 2007 Moonlight Fire. Prior to that, no fires had been recorded in the Mud Lake unit since 1910.

The Mud Lake unit of the MLRNA is dominated by white fir (*Abies concolor*), and to a lesser extent red fir (*Abies magnifica*). The Wheeler Peak unit is has a greater diversity of tree species, with white fir, sugar pine (*Pinus lambertiana*), Jeffrey pine (*P. jeffreyi*), incense-cedar (*Calocedrus decurrens*), and Douglas-fir (*Pseudotsuga menziesii*) co-dominating.

Existing conditions in the stand

Wheeler Peak: The Wheeler Peak unit contains the world's largest Baker cypress, with a diameter at breast height (dbh) of 56 inches and a height of 71 feet (Fig. 26). In addition to this champion tree, several other Baker cypress trees within the Wheeler Peak unit are over 36 inches dbh. These large trees occur on a largely unvegetated, rocky ridgetop.

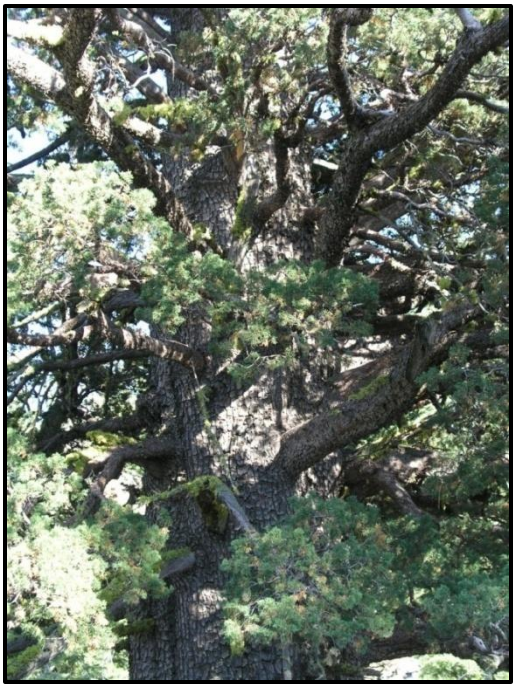

Figure. 26. Baker cypress champion tree, Wheeler Peak site.

The Wheeler Peak population of Baker cypress is younger than the Mud Lake population. The average age of trees in our plots at Wheeler Peak was 95 years, with a range of between 46 and 158 years. Keeler-Wolf (1985) suggested that this site is in an earlier successional stage than the Mud Lake population.

The Wheeler Peak population was relatively healthy compared to other populations across the range of the species. The average crown condition was less than 50 percent dead or dying, just slightly over the range-wide average of 44 percent. Baker cypress trees at the Wheeler Peak site were among the largest in dbh across the range of the species, averaging 9.8 inches.

While there are some areas of competition from white fir within the Wheeler Peak site, much of the unit is characterized by small, dense groves of Baker cypress isolated from one another by open, rocky soil. Most cypress trees in our plots were within three feet in height of other tree species within the stand. We did not observe any seedlings at the Wheeler Peak site.

Mud Lake: Prior to the 2007 Moonlight Fire, Baker cypress at the Mud Lake unit averaged 135 years of age. There were no trees younger than 100 years in our plots at the Mud Lake site, where the range of ages was between 101 and 167. We saw no seedlings in any of our plots prior to the Moonlight Fire.

Figure 27. Dead and dying Baker cypress at the Mud Lake site.

The Baker cypress stand at the Mud Lake unit was very unhealthy prior to the Moonlight fire (Fig 27). Cypress trees in our plots were 87percent dead or dying and represented only 28 percent of total stand density. Fire suppression at the MLRNA had allowed dense thickets of shade-tolerant white fir to dominate the stand, resulting in high levels of cypress mortality (Wagener and Quick 1963, Keeler-Wolf 1985). Other species averaged nine feet taller than Baker cypress in our plots. This competition for light produced some of the tallest known Baker cypress, measuring up to 100 feet in height. The decline of Baker cypress at the Mud Lake site due to competition was first noted by Wagener and Quick (1963) and had been recognized repeatedly since that time (Keeler-Wolf 1985). Prior to the 2007 Moonlight fire, there was significant concern that without immediate action to reintroduce fire to this population, it would be extirpated.

Figure 28. 2007 Moonlight Fire.

After the 2007 Moonlight Fire (Fig. 28), substantial cypress regeneration was observed. Despite low densities of living mature cypress in the stand prior to the fire, these residual trees had sufficient canopy seed storage to produce numerous seedlings. We found seedling densities of up to 85 seedlings/m2 in plots with only three living cypress prior to the fire. Pre-fire data indicated that even plots with only three Baker cypress adult trees prior to the fire could have dispersed an average of 15000 viable seeds after the fire. The density of mature cypress in the stand did not significantly affect post-fire cypress seedling density (Fig. 29).

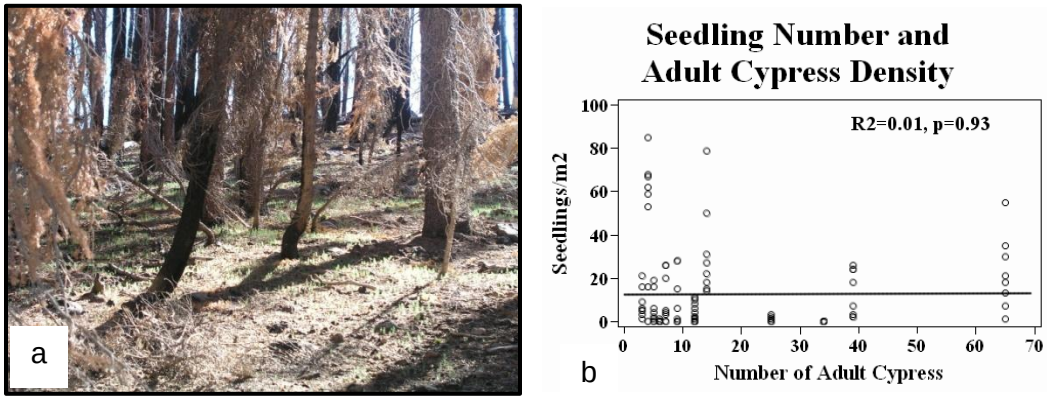

Figure 29. Cypress seedling densities were high after the Moonlight fire (a). Adult cypress density did not significantly affect seedling density (b).

We found that fire severity was the strongest predictor of post-fire seedling density. Plots with higher scorch and char heights, and more percent crown scorch volume, had greater numbers of seedlings (Fig 30). Plots with higher soil burn severity also had significantly higher seedling density.

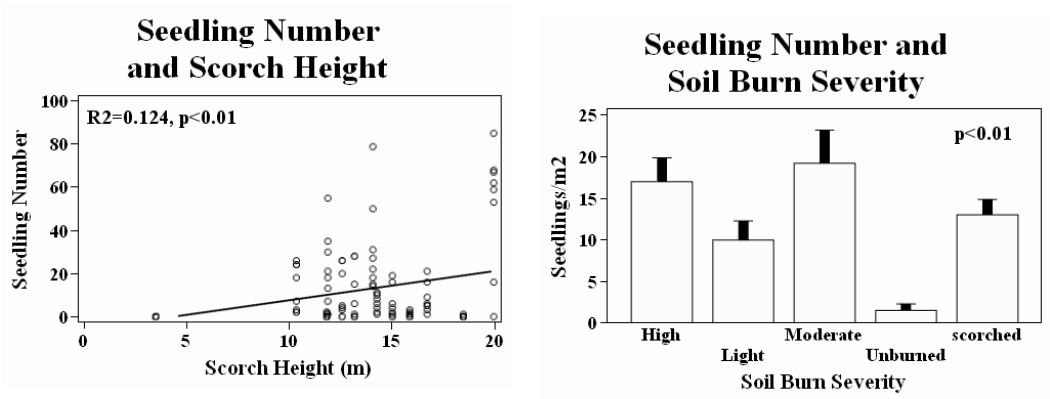

Figure 30. Cypress seedling densities were high after the Moonlight fire (a). Adult cypress density did not significantly affect seedling density (b).

Current fire conditions

Mud Lake: Prior to the 2007 Moonlight Fire, we measured an average of over 400 tons/acre of fuels at the Mud Lake site. There were very few surface fuels remaining after the Moonlight Fire (Fig. 31). Currently there is a high density of snags throughout most of the stand, and potential fire hazard may increase over time as these snags decay. Another fire at the Mud Lake Unit would likely be very destructive to the Baker cypress population there if it were to occur before trees mature.

Figure 31. High severity fire effects after the 2007 Moonlight Fire.

Wheeler Peak: We measured an average of 167 tons/acre of fuels at the Wheeler Peak unit of the MLRNA. This is among the lowest fuel loadings observed within Baker cypress populations range-wide, but would likely still be sufficient to sustain a wildfire if a natural ignition were to occur at the site.

Management recommendations

- Fire suppression is recommended at the Mud Lake site until Baker cypress trees are able to mature and develop a canopy seed bank.
- Fire suppression is not recommended for the Wheeler Peak unit, where older trees likely have sufficient seed storage to regenerate the population.
- Limited thinning of the Wheeler Peak stand, particularly on lower slopes where cypress become less dominant, might be appropriate.

Timbered Crater Baker Cypress Population

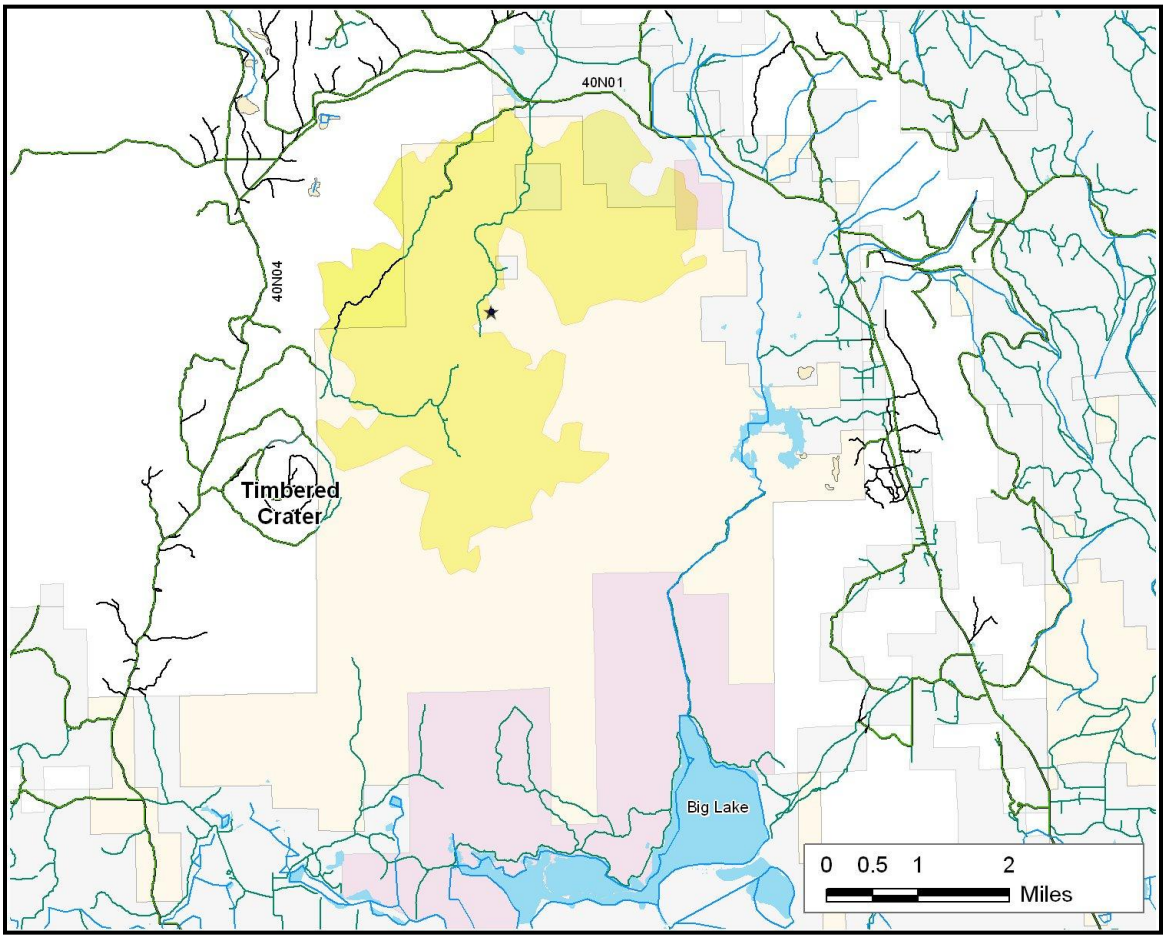

Figure 32. Map of Baker cypress population at Timbered Crater site.

General Description

Baker cypress at the Timbered Crater site are scattered across a large volcanic crater and surrounding lava flows on the western edge of the Modoc Plateau, approximately six miles west of the boundary between Modoc, Shasta, and Lassen Counties and 12 miles north of the town of Fall River Mills in Shasta County, California (Fig 32, 33).

Figure 33. Overview of Timbered Crater site.

Legal: T39N, R4E, Sections 23, 14, 11 and 12.

UTM at center point: NAD83, Zone 10, Easting (X) 630942, Northing (Y) 4561371.

Elevation: From 3500-4000 feet on predominantly flat slopes.

Figure 34. Typical stand of Baker cypress at Timbered Crater

The Timbered Crater site supports the largest population and type locality for Baker cypress (Fig. 34). This population occupies approximately 7000 acres, primarily growing in monospecific stands. The Baker cypress population is located within the Timbered Crater Wilderness Study Area (WSA), an 18,000-acre area managed by the Bureau of Land Management (BLM) to preserve the unique wilderness characteristics of the site. The Timbered Crater WSA supports several other rare and endangered plant species and is an excellent example of the geology of an extinct volcanic crater (Fig. 35).

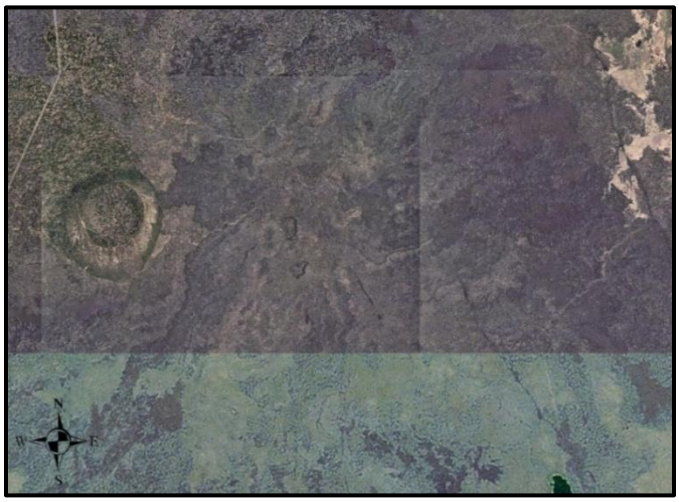

Figure 35. Aerial photo of Timbered Crater site.

Soil type – Volcanic

Timbered Crater lies at the junction of the Great Basin and Cascade Mountain ecosystems. Baker cypress is the dominant tree at the site. Other species present include knobcone pine (*Pinus attenuata*), ponderosa pine (P. ponderosa), and Oregon white oak (*Quercus garryana*). The understory is dominated by green leaf manzanita (*Arctostaphylos patula*).

Existing conditions in the stand

Figure 36. Regeneration after 2000 Adobe Fire.

The average age of trees cored at the Timbered Crater site was 70 years; however, there was a large diversity of age classes present within the population, with cored trees ranging from 25-125 years of age. We saw evidence of regeneration at Timbered Crater in an area burned by the 2000 Adobe Fire (Fig. 36).

Baker cypress at the Timbered Crater site experienced very little competition. Baker cypress represented an average of 97 percent of total stand density, and averaged six feet taller in height than other tree species in our plots. Canopy seed storage at Timbered Crater was relatively low, in part because cypress densities averaged only 67 trees per acre, and cone production averaged only 100-250 cones per tree. However, we only sampled six individual locations at Timbered Crater, and there is likely to be significant variation in stand characteristics across this exceptionally large population.

Current fire conditions

Due to its remote location and inaccessibility, fires have not been suppressed within the Timbered Crater area. Fires have been recorded there in 1910, 1977, 1992, and 2000.

Fuel loads at the Timbered Crater site were the lowest measured across the range of Baker cypress at 45 tons/acre. The site is characterized by numerous lava flows and outcrops. The very thin volcanic soils limit the productivity of the site and limit fuel accumulation (Fig. 37). The relatively frequent fire regime at Timbered Crater may also explain the low amount of fuels present there.

Figure 37. Rocky soils typical of Timbered

Management recommendations

The Timbered Crater Baker cypress population is the most robust population of Baker cypress known. The unproductive soils and remote location of this population have allowed it to flourish in the absence of competition and fire suppression or other detrimental management activities. Continued protection of this area and a policy of not suppressing fires here will likely maintain this impressive stand of Baker cypress without any other management actions.

Hamburg Baker Cypress Stand

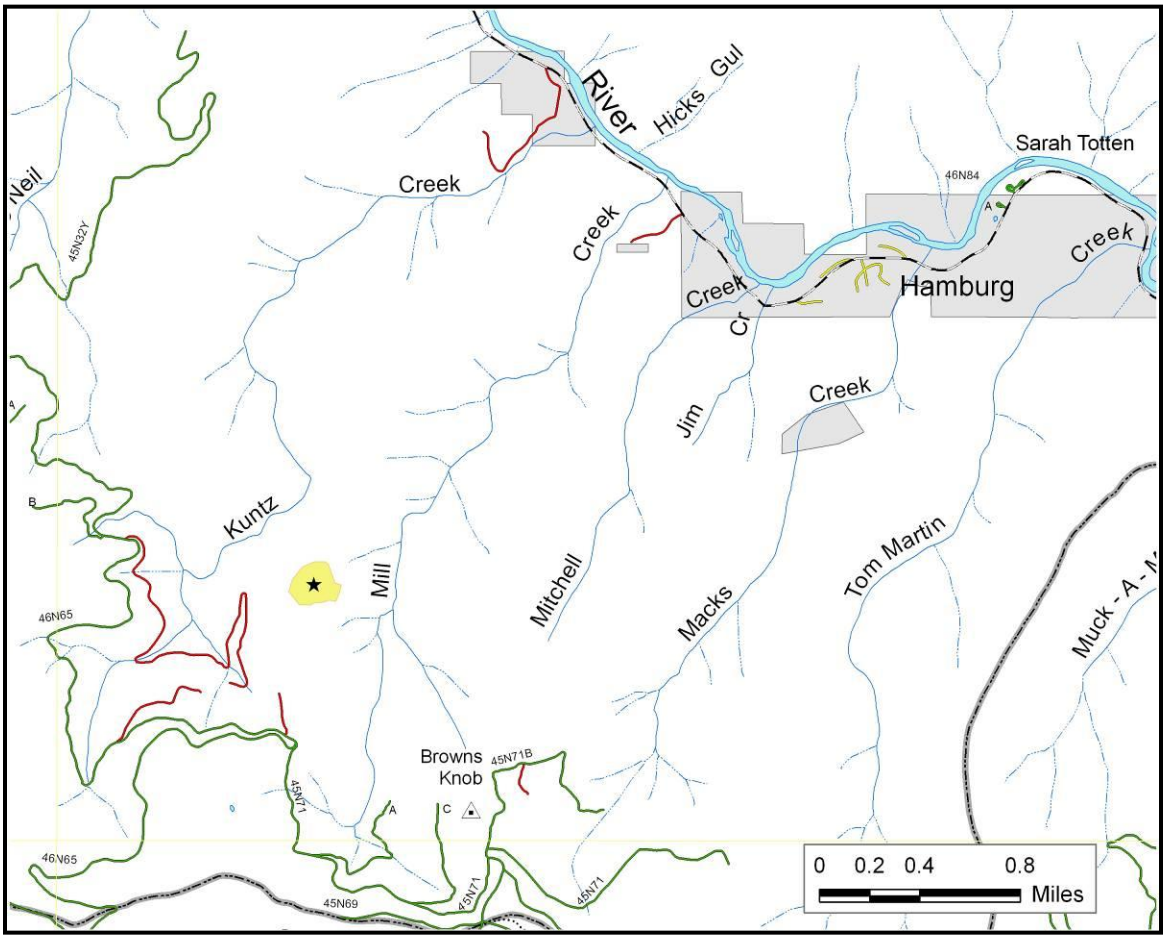

Figure 38. Map of Baker cypress population at Hamburg site.

General Description

This population is located near the town of Hamburg on the Klamath River between the Kuntze and Mill Creek drainages (Fig 38).

Legal: T45N R11W Sec. 9 NE

UTM at center point: NAD83 10T
Easting (X) 491162
Northing (Y) 4623646

Elevation ranges between 4480 and 5120 feet. Slope ranges from 70 to 83 percent with a northeast aspect.

Figure 39. Typical group of trees at Hamburg

This stand covers approximately 16 acres but not all of this area is Baker

cypress (Fig 39). Some areas are rocky talus slopes without dense tree coverage. The exact range of this population is difficult to survey because of the steepness of the slope.

Soil type – Peridotite

There are no recorded fire perimeters or other activities for this site. This stand was originally described in the literature by Dodd (1992).

Trees within the stand are intermixed with Douglas fir (*Pseudotsuga menziesii*) and a small amount of white fir (*Abies concolor*), Jeffrey pine (*Pinus jeffreyi*), and incense cedar (*Calocedrus decurrens*). The understory is dominated but huckleberry oak (*Quercus vaccinifolia*).

Existing conditions in the stand

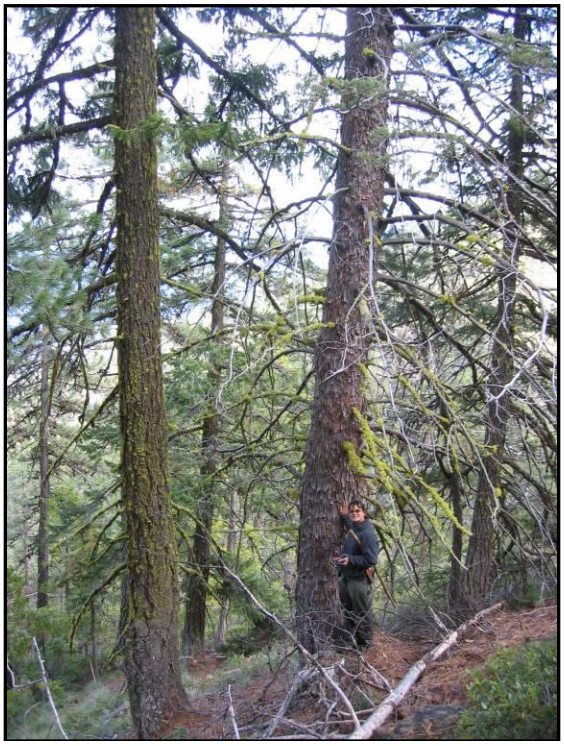

Figure 40. Large diameter Baker cypress at Hamburg

All trees cored measured between 116 to 169 years of age.

Age diversity is minimal. Cored trees represented mixed ages in a 54 year spread. This may represent multiple age groups, but further data is necessary to verify this. What is evident is that there are few trees younger than 120 years within the stand (Fig 40).

There is little to no regeneration occurring at present. There were five saplings measuring between two and four inches in diameter in one of three plots. The two other plots had no saplings. No seedlings were found in any plot.

Trees in this stand are healthy. The trees within the plot measure between 17 and 65 feet in height and ranged between 4 and 23 inches in diameter. Overall, the trees have healthy canopies and there is only a small amount of rot, given the age of the trees. While there is evidence of a few dead Baker cypress in the understory, most of these do not appear to be recent. The biggest concern for this stand is the lack of regeneration and the encroachment of Douglas fir into the stand.

Douglas fir is the main competitor to Baker cypress in this stand. In two of the plots, the number of Douglas fir was equal to or greater than the number of Baker cypress. Further exploration of this slope is necessary to determine if Baker cypress at one time covered a larger extent. Overall, the amount of rock and steepness of slope in this area may limit the amount of canopy closure and prevent the elimination of the Baker cypress in this area.

Canopy seed storage at present is adequate to regenerate the site given a stand replacing fire. Trees have a low overall cone number with an average of 50 to 100 cones per tree. Two of the trees measure had up to 1000 cones per tree, but on average trees had 50 to 100 cones per trees

Current fire conditions

As mentioned above, there are no large fires recorded at this site nor did we observe any fire scars or charred boles in the immediate vicinity during surveying. However, there are 723 fire starts recorded within the fifth field watershed since 1911, eight of those within 1000 meters of the population. Over 70 percent of these starts were lightning caused. This indicates a high probability of a fire occurring in this stand at some point.

Fuel load measures for this stand were low with few 100 or 1000-hour fuels and only light amounts of 1 and 10-hour fuels recorded. This may be due to the high percent cover by huckleberry oak (*Quercus vaccinifolia*) which would make it difficult to survey for fuels. In some plots huckleberry oak represented over 50 percent of the ground cover. Huckleberry oak is a resinous plant that can aid in the movement of surface fires and act as a ladder fuel to carry fire into the canopy (Howard, 2009). A natural fire in this stand during late summer conditions when lightning is most likely to occur would likely burn at a moderate intensity and may move into the canopy, killing off some of the trees and provide opening for regeneration. A natural fire in this stand may be beneficial and result in some regeneration.

Management recommendations

For long term success of the stand, a reduction in the percent of Douglas fir within the stand and an increase in the extent of Baker cypress are desirable. In addition, creation of a multi-aged stand by creating open areas for regeneration, while preserving a few of the older trees to act as a future seed bank, may provide the best combination of strategies for long-term survival of the population. The steepness of the slope and the difficulty of access may make it difficult to design a prescribed burn in this area. The ridge above the stand is a possible location to build a line that could be used to limit the spread of the fire. Further analysis by a skilled fuels technician will be needed.

Initiating regeneration in this stand within the next 5 to 10 years will be critical for its future survival.

Seiad Baker Cypress Stand

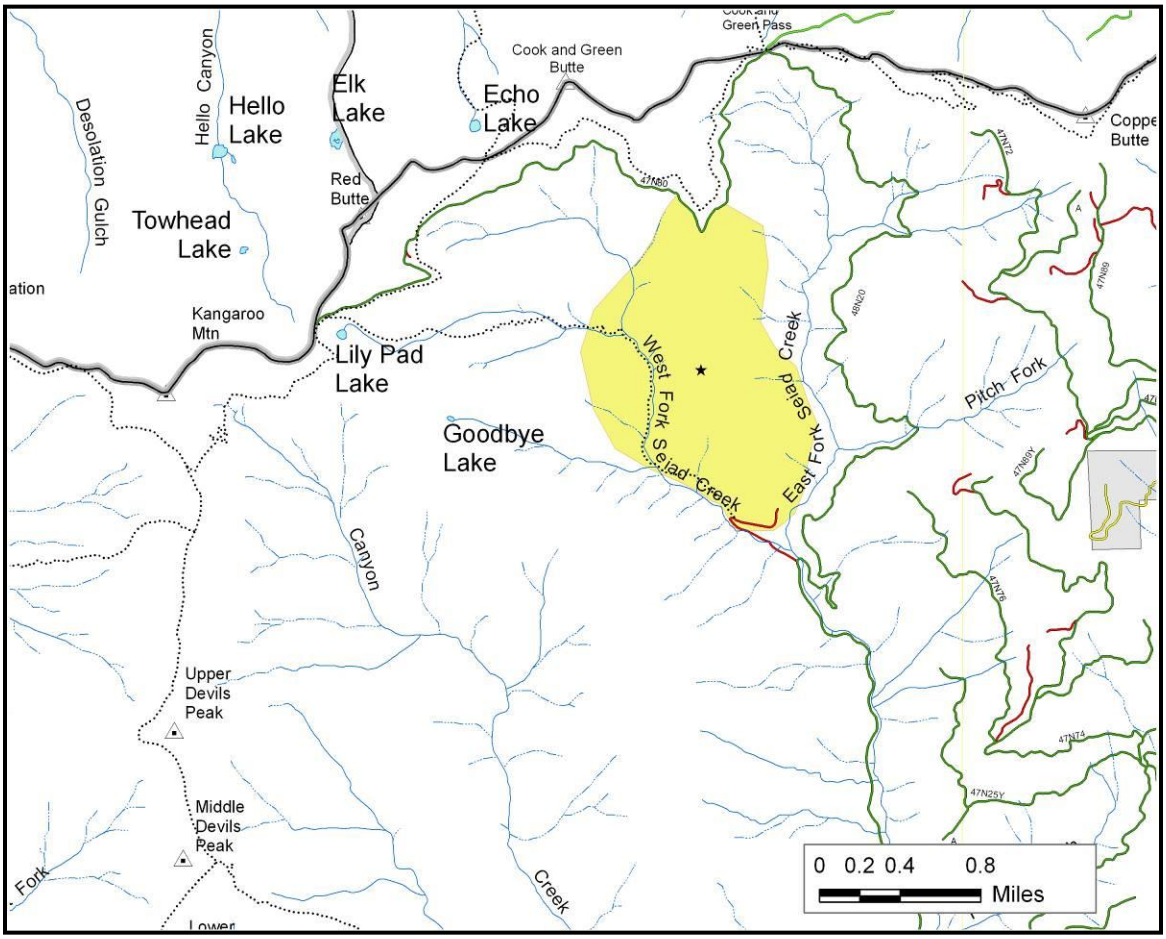

Figure 41. Map of Baker cypress population at Seiad site.

General Description

This population is located north of the Seiad Valley on the Klamath River within the Seiad Creek Watershed (Fig 41).

Legal: T47N R11W Sec. 17, 18, 19, 20

UTM at center point: NAD83 10T
Easting (X) 487449
Northing (Y) 4640780

Elevation ranges between 2700 and 5300 feet. Slope ranges from 30 to 75 percent.

This stand is the second largest stand covering approximately 800 acres. The

Figure 42. Dense Baker cypress stands intermixed with shrub areas at Seiad.

largest portion of the stand covers the east and west facing slopes above the West Fork of Seiad Creek with areas of dense trees intermingled with open rocky areas where tree cover is sparse and shrub cover is dominant (Fig 42).

Soil type – Peridotite

Until recently, this area was used for chromium mining (Ralph and Chau 2010). There have been several fires in the stand in the last 60 years. The eastern side of the stand was burned in the 1951 Three Devils fire. This appears to have been a high severity fire since much of the area within this fire perimeter is dominated by even-aged stands. The west side of the stand was burned in the 1987 Fort/ Copper fire. Observations after the fire indicate that this was a patchy burn with small areas of high intensity fire intermixed with other areas of low to moderate intensity burns (USDA 1991). This stand was set aside as a botanical special interest area in 1994.

On the upper slopes where conditions are rocky and dry, Baker cypress trees are interspersed with knob cone pine (*Pinus attenuata*) and Jeffrey pine (*Pinus jeffreyi*) with green-leaf manzanita (*Arctostaphylos patula*) and dwarf silk tassel (*Garrya buxifolia*) as the dominant understory shrubs. In more mesic areas close to the creek, Douglas fir (*Pseudotsuga menziesii*) and incense cedar (*Calocedrus decurrens*) are also present with huckleberry oak (*Quercus vaccinifolia*) in the understory (Fig 43).

Existing conditions in the stand

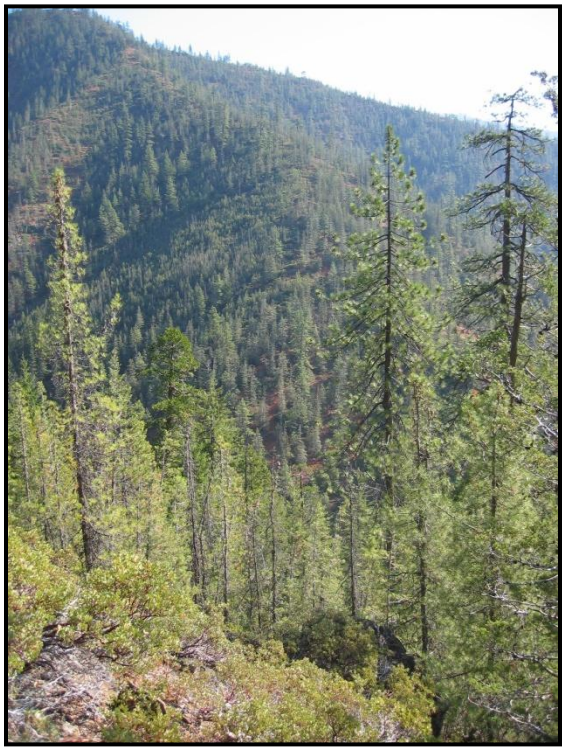

Figure 43. View across stand at Seiad.

Cored trees measured between 32 and 113 years. In general, many of the trees in this stand were difficult to core due to the amount of rot within the bole. Even trees appearing to have healthy canopies often have rot not only at the root collar but also at breast height.

The diversity of age classes varies across the stand and is dependent on the time since last fire. In areas where fire has occurred since 1950, stands are typically dense even-age stands of sapling size trees with as many as 800 trees in a tenth of an acre (Fig 44). In areas without recent fire, ages are more variable, often with several age cohorts and trees much more dispersed, with as low as 50 trees in a tenth of an acre. In these areas sapling size trees make up less than half of the total tree density. There were a few trees that measured under 4.5” dbh and so were considered seedlings, but these individuals are most likely in the same age class as most of the larger trees in

the stand. Within the six plots surveyed, only four individuals were found that could be considered new progeny because they germinated in the last five years.

This stand has a lower number of cones per tree than other stands. On average, most trees measured had 50 to 100 cones per tree. There were examples of trees with as many as 2500 to 5000 cones. These are generally larger trees found in open areas. The overall lower cone number at this site may be related to the density of the trees since the closed canopy of dense stands limits cone production.

However, low cone numbers are more likely due to nutrient poor soils. Populations at Hamburg and Huckleberry Mountain, experience similar soil conditions and also have fewer cones per tree than other sites.

Seiad also has the lowest percent viable seeds. On average for all stands, 15 percent of the seeds tested were viable while for Seiad alone only 6 percent of the seeds tested were viable. This, in combination with the low number of cones per trees, means that there are fewer numbers of viable seeds per tree.

For example, comparing two similar trees with equal cone numbers (Table 3) demonstrates that differences in seed viability have a large affect on total seed viability. In this example, the tree at Hamburg has over two times the number of viable seeds as the tree at Seiad. However, this does not appear to affect the ability of a stand to regenerate after fire. Even in an area with only 50 trees per acre, there would be over 10,000 viable seeds stored within the canopy – sufficient numbers to regenerate the stand after fire.

Table 3. Seed viability differences between two stands with different % viability

Site	Cones/ Tree	Seeds per Cone	% closed cones	% seed viability	Viable seeds
Seiad	100	54	67 %	6 %	217
Hamburg	100	57	70 %	15%	598

Overall, the population appears to be in good condition. The amount of encroachment from other conifer species is lower than at other sites. On the east facing slope, knob cone pine is the biggest competitor to the Baker cypress. Knob cone is the dominant tree at higher elevations, but Baker cypress is dominant at the lower elevations. Dead knob cone were often observed in areas where there was a high density of Baker cypress. While other conifer species are present on the west and south facing slopes, overall these are not encroaching on Baker cypress. Some encroachment is occurring in the more mesic areas with deep soils, where Douglas fir and incense cedar have overtopped the cypress.

Rot within the trees may be a concern for this population. The trees in this stand have a greater amount of tree rot than those at the other locations. The reasons for this are not clear. It may be that trees appearing young are actually much older and therefore have developed rot overtime similar to other stands. Or, the extensive rot may be due to other unknown factors. Further study is necessary to determine what factors are contributing to the rot and how this may affect the overall health of the stand. In general, all Baker cypress develop rot overtime and most remain healthy for many years and continue to produce cones.

Current fire conditions

There is a high potential for fire ignitions to naturally occur in this stand. There are 726 fire starts recorded within the fifth field watershed since 1911, 12 of which fall within 1000 meters of the population. Over 70 percent of these starts were lightning caused. As mentioned above, two large fires have burned through portions of the stand since 1950 – one in 1951 and one in 1987. Both were lightning-caused fires. While fire starts may occur in this area, the likelihood of a high intensity fire is not clear. For example, in September of 2001, there was a lightning strike within southwestern corner of the stand, but this fire was either suppressed or did not spread.

Fuel load measures for this stand were moderate with an average three - 100 or 1000-hour fuels per transect. Ten-hour fuels were fairly light with an average of 8 per transect and 1-hour fuels were the heaviest with an average of 40 per transect. This may be due to the high percent cover by huckleberry oak (*Quercus vaccinifolia*) which would make it difficult to survey for fuels. In some plots huckleberry oak represented over 50 percent of the ground cover. Huckleberry oak is a resinous plant that can aid in the movement of surface fires and act as a ladder fuel to carry fire into the canopy (Howard 2009). In addition, the density of Baker cypress in some areas could also contribute to the fuel load. A natural fire in this stand during late summer conditions when lightning is common would likely burn at a moderate intensity, killing off some of the trees and providing openings for regeneration. A natural fire in this stand may be beneficial and result in some regeneration.

Figure 44. Dense sapling stand after 1951 fire at Seiad.

One advantage that this stand has over some of the smaller stands is the variety of topography present at the site. A natural fire within this stand is unlikely to burn the entire stand due to the different aspects and diversity of stand densities and age classes within the area. Also, since part of the stand runs along the west fork of Seiad Creek, mesic conditions in this area may limit the spread of fire there. This geographic diversity allows for a mix of age classes across the stand.

Management recommendations

For long term success of the stand, a continuation of the natural processes already occurring in this area is desirable. It is important that some fire occur in this stand to maintain a healthy population. Fire would ensure that new progeny develop and reduce the chance of loss due to disease and decay. More frequent fires in this area could benefit this stand. At present, this stand can persist without any fire for some time. There is not as much impact from encroachment. Although rot is a factor, this does not seem to be affecting the health of the

canopy or the production of cones, however, more frequent fires would allow for increased regeneration at this site.

One management option would be to allow natural fires to burn through this stand. Lightning strikes have occurred in this stand and will most likely continue. Depending on the timing of the lightning, a lightning started fire has the potential to move through part of the stand and create the conditions suitable for regeneration. However, a natural fire may not occur at the right time or location to allow the fire to burn because of the distance to urban areas.

Prescribed fire is another management option, although the steepness of the slope and the difficulty of access may make it difficult to design a prescribed burn in this area. Further analysis by a skilled fuels technician will be needed. Overall, initiating regeneration in this stand within the next 10 to 20 years would best support the long term health of the stand.

Goosenest Baker Cypress Stand

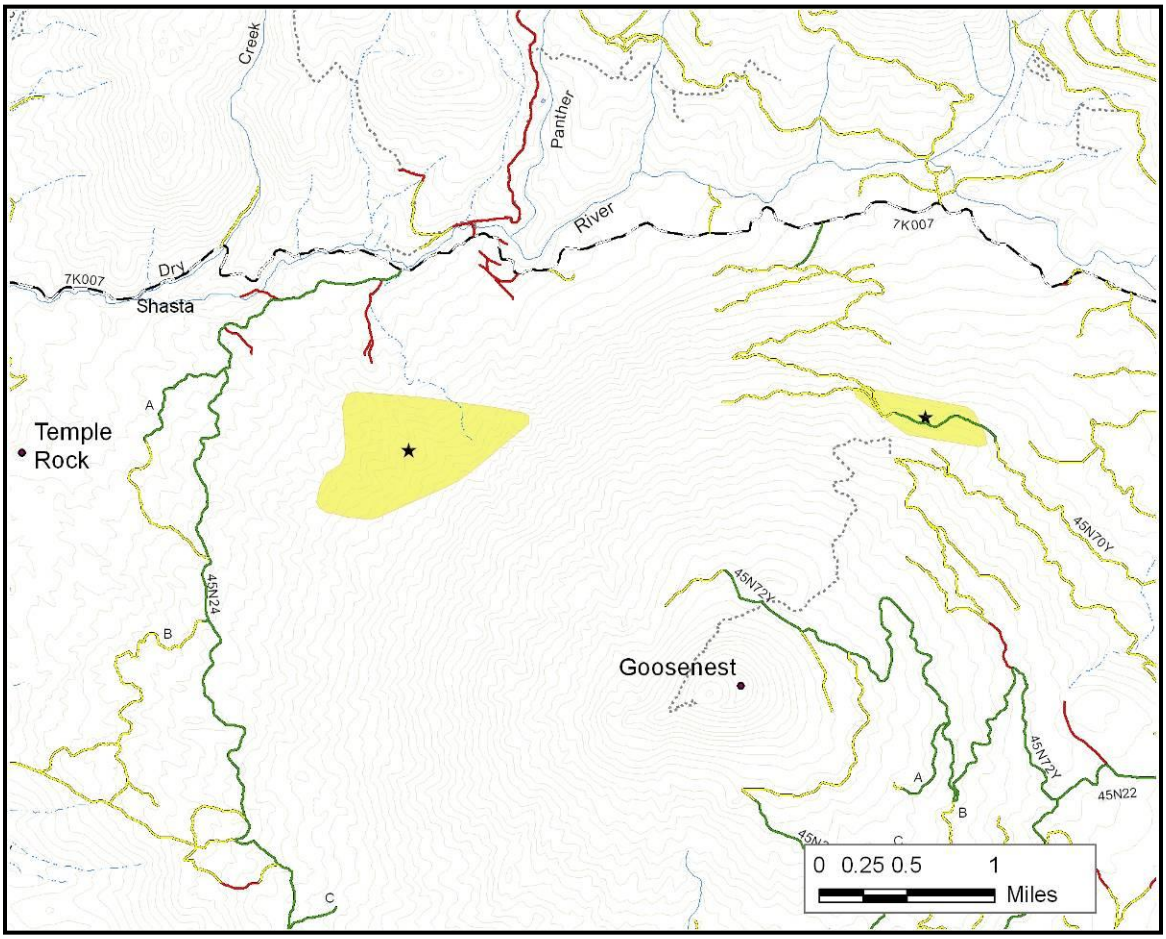

Figure 45. Map of Baker cypress population at Goosenest Mountain site.

General Description

This population is located east of Yreka, California on the Northwest and Northeast slopes of Goosenest Mountain (Fig 45).

Legal: T45N R4W Sec. 13, 14, 23, 24, R3W Sec. 16, 17, 21

UTM at center point:

NW population: NAD83 10T Easting (X) 566375 Northing (Y) 4621419

NE population: NAD83 10T Easting (X) 561614 Northing (Y) 4621114

Figure 46. Open lava flows separate islands of Baker cypress on westside of Goosenest mountain.

Elevation ranges between 4200 and 5300 feet on the west side and 5840 and 6800 on the east side. Slope ranges from 20 to 60 percent with northwest and northeast aspects.

The western side of the stand covers approximated 350 acres. The stand is broken up by rocky lava flows approximately 50 to 100 feet across that divide the stand into dense islands of trees in areas where there is sufficient soil depth (Fig 46, 47). On the eastern side, Baker cypress has sparse cover over approximately 85 acres with a few scattered older trees occurring within a white fir (Abies concolor) dominated stand. This area is primarily Forest Service land surrounded by private timber land that has been harvested.

Soil type – Volcanic

There are few recorded fire perimeters or other activities for this area. This stand was originally described in the literature by Wolf (1948).

Baker cypress trees on the west side are intermixed with Douglas fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*). The understory is dominated by chinquapin (*Chrysolepis sempervirens*) with patches of manzanita (*Arctostaphylos patula*), Scouler's willow (*Salix scouleriana*), and mountain mahogany (both *Cercocarpus betuloides* and *C. ledifolius*). On the east side, white fir is dominant with only a small amount of Baker cypress present. Similar to the west side, the understory is dominated by Chinquapin.

Figure 47. Large tree at Goosenest.

Existing conditions in the stand

All trees cored measured between 53 and 163 years of age. Ages varied depending on location in the stand. Three of the plots had an average age of between 74 and 80 years, while one plot higher on the slope had an average age of 148 years. No readable cores were obtained on east side of the stand.

There is a limited amount of regeneration occurring within this stand. One plot had four new progeny counted within a tenth-acre plot – three other plots had some older seedlings and saplings. No seedlings were found on the eastside, however, five seedlings were counted adjacent to the plot in an area where a large white fir had fallen creating a small opening. This indicates that some disturbance can create the conditions necessary for germination to take place without fire.

Canopy seed storage on the west side is high. Trees on this side had higher cone

numbers than at any other location. On average, individual trees had 250 to 500 cones per tree. Because of the distribution of trees into islands, trees along the edge of the stands and in the open areas where full sunlight is available have the greatest cone numbers (Fig 48). On the eastside, Baker cypress have fewer cones due to the high density of white fire. In this area cone production is limited to the very tops of the trees.

Figure 48. Tree with heavy cone production at Goosenest.

Douglas fir is the main competitor to Baker cypress on the west side. At present, Baker cypress is still the dominant tree; however, without fire Douglas fir may begin to overtop the Baker cypress. Both Douglas fir and white fir seedlings and saplings were present in the understory of the plots surveyed. On the east side, white fir is the main competitor to Baker cypress and is now the dominant species here. There is only a remnant of surviving Baker cypress in these stands and large numbers of dead Baker cypress are present in the understory (Fig 49).

Current fire conditions

There are few fires recorded for this area. In 1992, a fire of approximately 270 acres occurred on the slope below the eastside population about one mile from the stand. On the west side, there is a fire recorded in 1918 just below the population. While this fire perimeter does not indicate that the Baker cypress population was affected, the age range of the trees in the lower half of the west side may indicate that part of the stand burned at this time. In 2008, a lightning strike occurred on the western side that did not spread beyond a tenth acre. Max Creasy, who also worked on this project, indicated that there was also a younger stand of trees near the northern edge of the population (pers. communication). Because the lava flows can act as a fire break it is possible that they limit the spread of fire to only a small area.

Figure 49. Dense fuels and dead Baker cypress in forest understory on eastside of Goosenest Mtn.

There is the potential for fire to occur in this stand in the future. There are 280 fire starts recorded within the fifth field watershed since 1911; three of these are within the population on the west side. Approximately 78 percent of the strikes were lightning caused. Fewer strikes are recorded for the east side than for the west side.

Management Recommendations

East side: Without management action, this part of the stand is at high risk to be lost within the next 10 years. There are few surviving Baker cypress trees remaining and many of these will not survive for long. There may not be enough viable seed in this area since cone production has been reduced for some time. If a natural fire was to occur within this area, Baker cypress would likely germinate and may increase in number in this area, but it is uncertain if long term survival is possible.

It could be debated whether it is important to save this population. Chemical and morphological studies have found that trees within this population show similar characteristics to those at the northern end of the west side population (Dodd 1994). With a larger, healthy stand on the adjacent slope it may not be necessary to manage this area for Baker Cypress. However, with the limited distribution of this species, it may be important to retain whatever existing remnant trees are present on the landscape.

This stand is located within a Late Seral Reserve. One recommendation is that small patches be opened and maintained as Baker cypress habitat while maintaining other areas as Late seral habitat. Further discussion is needed regarding this stand.

West side: For long term success of this stand, a continuation of the natural processes already occurring in this area is desirable. It is important that some fire occur in this stand to maintain a healthy population. At present, this stand can persist without any fire for some time. There is not as much impact from encroachment, however, more frequent fires would allow for increased regeneration at this site.

One management option would be to allow natural fires to burn through this stand. Lightning strikes have occurred in this stand and will most likely continue. The lava flows can act as natural fire breaks to limit the spread of fire. A policy of not suppressing fires here will likely maintain this stand of Baker cypress without any other management actions.

Prescribed fire is another management option, although the lack of water and the poor access to the site may make it difficult to design a prescribed burn in this area. Further analysis by a skilled fuels technician will be needed. Overall, initiating regeneration in this stand within the next 30 years would best support the long term health of the stand.

Flounce Rock Baker Cypress Stand

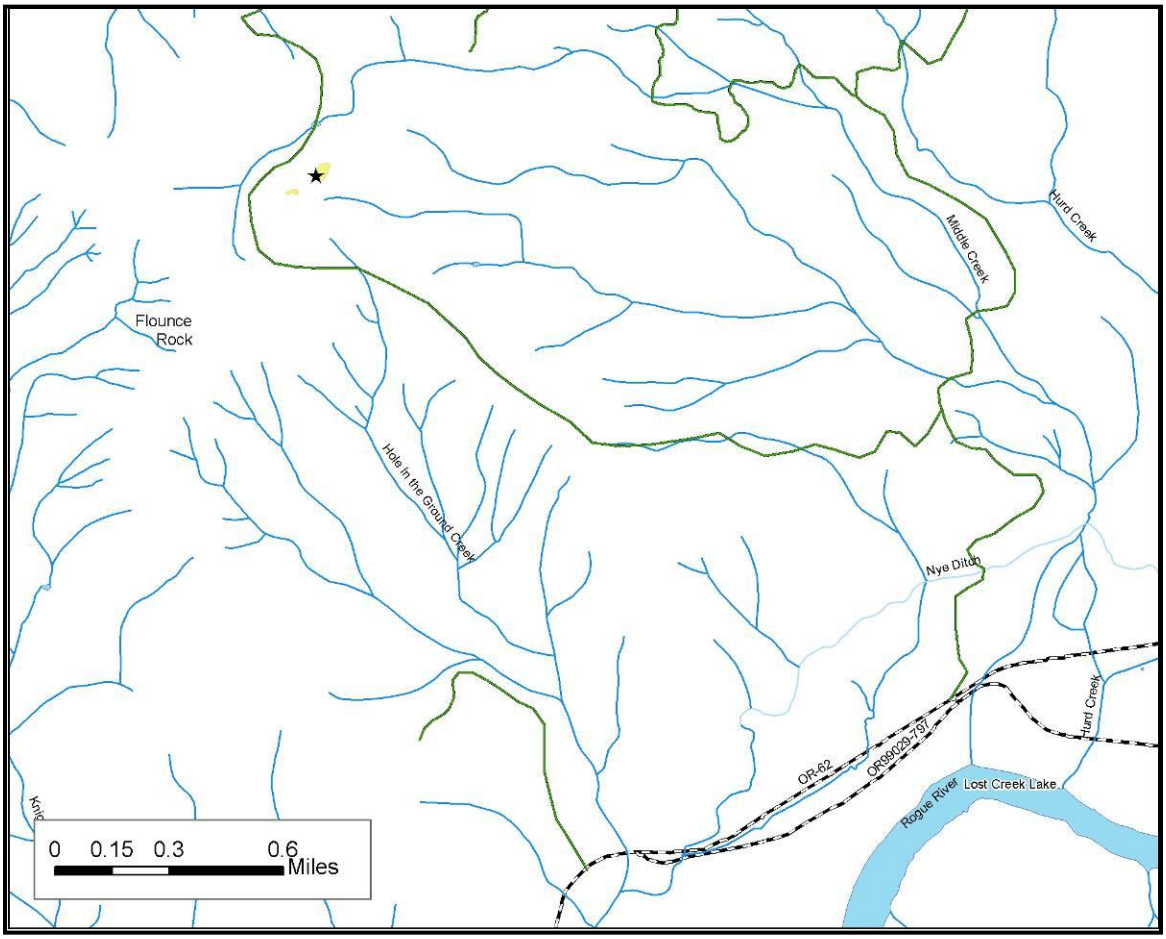

Figure 50. Map of Baker cypress population at Flounce Rock site.

General Description

This population is located in Oregon near Flounce Rock, a geographic feature just north of the Lost Creek Reservoir, east of the town of Prospect (Fig 50).

Legal: T33S R2E Sec. 33 NE

UTM at center point: NAD83 10T
Easting (X) 532492
Northing (Y) 4731419

Elevation ranges between 4030 and 4095 feet. Slope is approximately 5 percent with a northeast aspect.

Figure 51. Baker cypress at Flounce Rock.

This stand is less than one acre in size (Fig 51). There is one main dense grove where the majority of trees are located. The second smaller area contains a few large trees with a number of planted seedlings. The stand is bordered by an open, rocky, grass and shrub dominated habitat on one side, and dense conifers on the other. The land ownership in the area is a checkerboard of private and federal lands managed by the Bureau of Land Management.

Soil type – Metasedimentary

This is a small group of Baker cypress trees located within a larger Douglas fir (*Pseudotsuga menziesii*) forest. One side of the population is bordered by open meadow with pine and incense cedar (*Calocedrus decurrens*). In the open small patches of chaparral grow adjacent to the stand. Another side of the population is bordered by a recently harvested timber slope. There are no recorded fire perimeters or other activities for this site. This stand was originally described by Oliver Matthews in 1953 (Little 1970).

Trees within the stand are intermixed with Douglas fir (*Pseudotsuga menziesii*) and some Oregon white oak (*Quercus garryana*) and willow. There is also a small amount of madrone (*Arbutus menziesii*) and dogwood (*Cornus nuttallii*) present in the stand. There is very little understory cover within the stand due to the high fuel load – typically less than 10% herb cover.

Existing conditions in the stand

Figure 52. Dense fuels and dead Baker cypress in understory at Flounce Rock.

Cross-sections collected from this stand were measured to be between 108 and 174 years of age. Samples were difficult to age due to the amount of rot present. Much of the stand is extremely decadent with a number of recently fallen trees (Fig 52).

Cone numbers for this stand were variable depending on location. In the central dense part of the stand, trees had less than 100 cones per tree. Trees on the outside edge near the open areas had much high cone numbers with 500-2500 cones per tree. The low cone numbers in the center of the stand is most likely the result of shading from the Douglas fir trees. Collected cones had an average of 34 seeds per cone. This is low seed number compared to some of the other sites. Seed viability was also somewhat low at nine percent.

There is little evidence of Baker cypress regeneration occurring naturally in this stand. The majority of seedlings measured within the sample plot were Oregon white oak – there was only one Baker cypress seedling. The Bureau of Land Management has been working to establish new seedlings. There are a number of Baker cypress saplings planted at the site, however, elk

and deer herbivory has been a concern. Exclosures have been set up to protect the trees and reduce the damage. This has become a problem in recent years as the trees have completely filled the exclosures. The exclosures need to be removed so as not to further inhibit growth.

Current fire conditions

There is a potential for fire ignitions to naturally occur in this stand. There are 169 fire starts recorded within the fifth field watershed since 1968, two of which occurred within 1000 meters of the population. Over 40 percent of these starts were lightning caused. Since 1986, three fires that were larger than a tenth of an acre have occurred within four miles of the stand. However, due to the presence of private land in this area, naturally occurring fires have the potential to cause extensive property damage.

Figure 53. Open meadow area adjacent to Baker cypress at Flounce Rock.

Fuel loads within this stand are heavy. There is a large number of dead cypress in the forest understory creating a build-up of 1000-hr fuels. This, in combination with the decadence of the surrounding stand, increases the potential for a stand replacing fire. Observations from 2007 Moonlight fire on the Plumas NF suggest that high intensity fire events may result in successful regeneration of Baker cypress. However, this may be a concern if the entire stand was replaced leaving no remaining individuals to provide a seed storage until the new generation has time to mature. One management option might be to protect individual trees away from the main population or isolated along the edge of the openings (Fig 53) to prevent the loss of all adult trees in the event of a fire.

Management Recommendations

The small size of this population and the current stand conditions indicate that it is critical that management actions be taken to maintain this stand. Without immediate action there is the potential for this population to be extirpated.

Recent activities by the Oregon Bureau of Land Management to plant a few Baker cypress in open areas may benefit the stand by developing younger trees to continue seed production as older trees die. The problem of herbivory by deer and elk is still a concern since the trees still require protection beyond when they outgrow the current exclosures. One suggestion is to create a larger exclosure around a larger number of trees and habitat, rather than making enclosures around individual trees. This would provide protection from herbivory while allowing trees to increase in girth and height.

Planning a prescription burn to create suitable habitat for regeneration is the best solution for this population. A controlled fire could remove a portion of the population and allow for

regeneration while maintaining other trees. The current above-ground seed storage should be adequate to successfully regenerate the stand.

One suggested short-term measure to ensure the survival of the population is to burn the small patches of manzanita adjacent to the stand and spread Baker cypress seed in this area. This would introduce a younger group of trees into the area and establish a source of seed to keep the population viable.

At the minimum, a seed collection should be made from this population with adequate genetic diversity so that the stand could be restored if conditions deteriorate.

Huckleberry Mountain Baker Cypress Stand

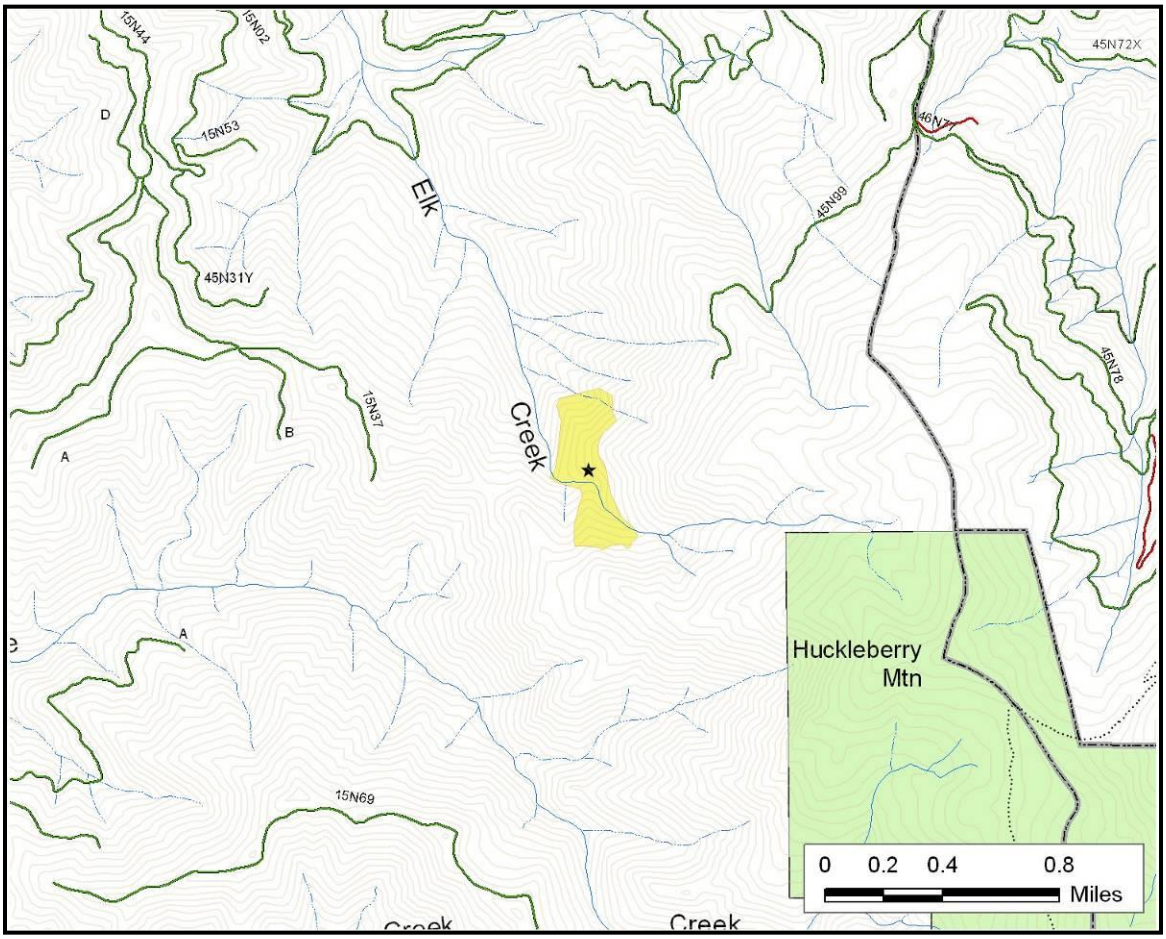

Figure 54. Map of Baker cypress population at Huckleberry Mountain site.

General Description

This stand is located at the head of the north fork of Elk Creek in the Klamath National Forest, just northeast of Huckleberry Mountain (Fig 54).

Legal: T15N R8E Sec. 15 NE & Sec. 10 SE

UTM at center point: NAD83 10T
Easting (X) 476215
Northing (Y) 4616427

Elevation ranges between 3600 and 4600 feet. Slope ranges from 40 to 78 percent. The majority of the stand has a north and west aspect (Fig 55).

Figure 55. Looking across to the north-facing slope of Baker cypress at Huckleberry Mountain.

This stand is approximately 55 acres in size. Griffin and Critchfield (1972) reported that Baker cypress at this site was first mapped in the 1938 VTM project. However, the population was not rediscovered until 1987. The dominant part of the stand covers the north and west facing slopes along Elk Creek in areas of dense trees intermingled with open rocky areas where tree cover is sparse and shrub cover is dominant. There are two fire perimeters – 1987 and 2008 – recorded for the area adjacent to this population.

Soil type – Peridotite

Trees within the stand are intermixed with Jeffrey pine (*Pinus jeffreyi*), Douglas fir (*Pseudotsuga menziesii*), sugar pine (*Pinus lambertiana*) and incense cedar (*Calocedrus decurrens*) close to the creek (Fig 56). In areas farther upslope, Baker cypress is mixed with knob cone pine (*Pinus attenuata*). The understory is dominated but huckleberry oak (*Quercus vaccinifolia*).

Existing conditions in the stand

Figure 56. Typical Baker cypress stand at Huckleberry Mountain.

All trees cored measure between 45 and 153 years of age. Overall, plots had an average age of 72 years. Age diversity was mixed throughout the stand. Older trees were scattered throughout the stand There were two areas with rock outcrops where much older trees were surviving (Fig 57). These were difficult to core due to the amount of rot present.

Trees in this stand are healthy, measuring between 14 and 77 feet in height and four to 20 inches in diameter at breast height. Soil conditions in some areas of the stand result in a slow rate of growth that makes it difficult to determine what is a seedling and what is a tree. For example, one 1-foot tall “seedling” measured 45 years of age while a similar sized tree measure 14 years (Fig 58). Only three seedlings were counted at this site that could be considered new progeny.

On average, most trees had 50 to 100 cones per tree. There were a number of trees with as many as 1000 to 2500 cones. Similar to Seiad, limited cone numbers are most likely a combination of poor nutrient soils and the density of Baker cypress trees in some areas of the stand. Seed viability at Huckleberry was 12 percent – almost double the percent viability at

Seiad. Given the density of trees and the high percent viability, canopy seed storage is currently not a limitation at this site.

Overall, the population appears to be in good condition. The amount of encroachment from other conifer species is lower than at other sites. In the areas adjacent to the creek there is a greater diversity of conifers species. In the areas farther upslope, Baker cypress is dominant and in some areas intermixed with knob cone. While is rot present within this stand although it is not as widespread as at Seiad.

Figure 57. Two older Baker cypress trees are still producing cones, even with only a portion of the bark viable.

Current fire conditions

Figure 58. Two Baker cypress cross-sections – one is 14 years and one is 45 years.

There is a potential for fire ignitions to naturally occur in this stand. There are 329 fire starts recorded within the fifth field watershed since 1911, eight of which fall within 1000 meters of the population. Over 78 percent of these starts were lightning caused. There are two large fires recorded at this site. The 1987 King Titus fire occurred adjacent to the western edge of the population and in 2008, the Panther fire stopped at the southern edge. The 1987 fire burned patches of the stand which resulted in small areas of regeneration.

Fuel load measures for this stand were moderate with an average three - 100 or 1000-hour fuels per transect. Ten-hour fuels were fairly light with an average of 6 per transect and 1-hour fuels were the heaviest with an average of 49 per transect. This may be due to the high percent cover by huckleberry oak (*Quercus vaccinifolia*) which would make it difficult to survey for fuels. In some plots huckleberry oak represented over 50 percent of the ground cover. Some areas of the stand have a high density of Baker cypress similar to Seiad. A natural fire in this stand during late summer conditions when lightning is common would likely burn at a moderate intensity, killing off some of the trees and providing openings for regeneration. A natural fire in this stand may be beneficial and result in some regeneration.

Management Recommendations

For long term success of the stand, it is important that some fire occur in this stand to maintain a healthy population. At present, this stand can persist without any fire for some time. There is not as much impact from encroachment and there is adequate cone production to regenerate the stand. However, more frequent fires in this area could benefit this stand. Fire would ensure that new progeny develop and reduce the chance of loss due to disease and decay.

One management option would be to allow natural fires to burn through this stand. Lightning strikes have occurred in this stand and will most likely continue. Depending on the timing of the lightning, a lightning started fire has the potential to move through part of the stand and create the conditions suitable for regeneration. This stand is located in a remote area and can burn without affecting urban areas. A policy of not suppressing fires here will likely maintain this stand of Baker cypress without any other management actions.

Prescribed fire is another management option, although the steepness of the slope and the difficulty of access may make it difficult to design a prescribed burn in this area. Further analysis by a skilled fuels technician will be needed. Overall, initiating regeneration in this stand within the next 10 to 20 years would best support the long term health of the stand.

Independence Baker Cypress Stand

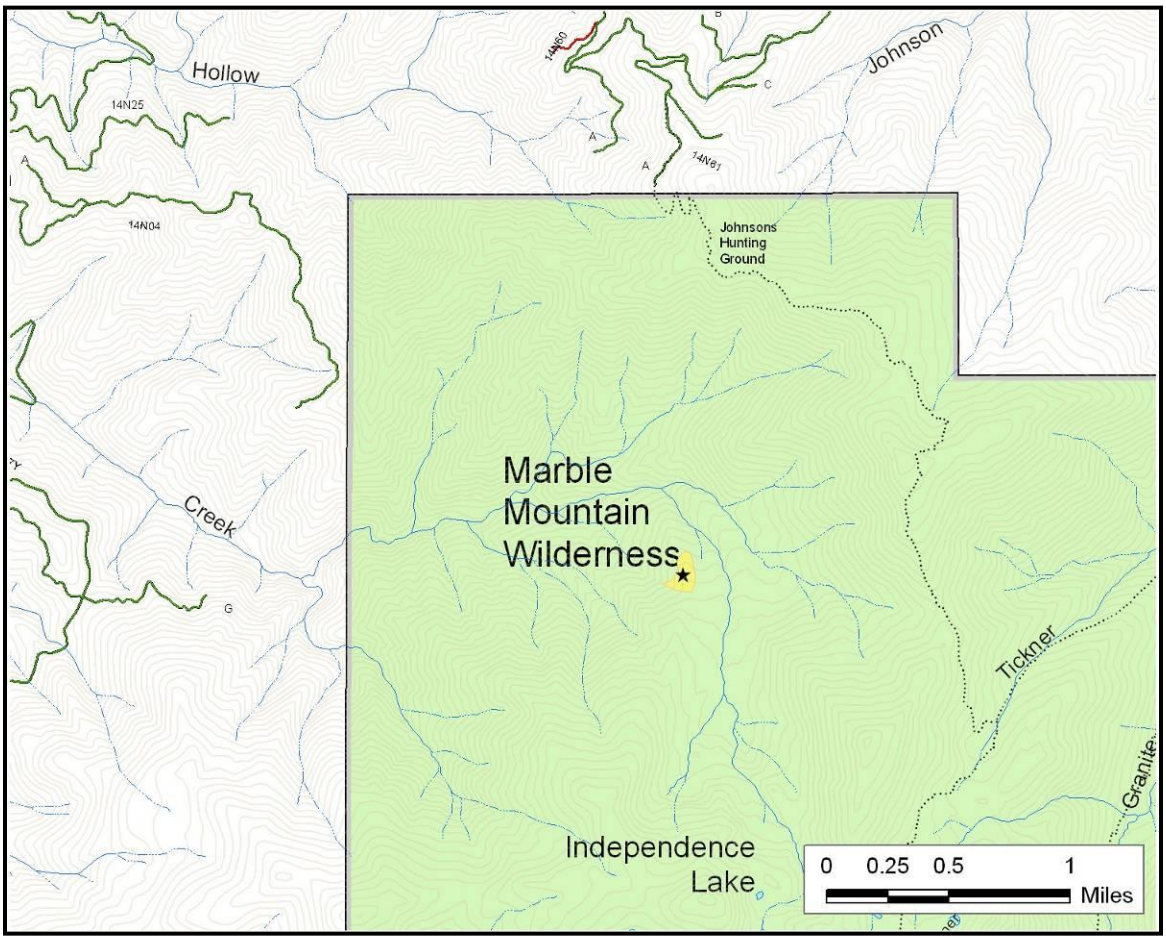

Figure 59. Map of Baker cypress population at Independence site.

General Description

This stand is located on the Happy Camp district of the Klamath National Forest in the Marble Mountain Wilderness. It is situated north of Ukonom Lake in the Independence Creek drainage (Fig 59).

Legal: T14N R7E Sec. 14 NE

UTM at center point: NAD83 10T
Easting (X) 470760
Northing (Y) 4605945

Elevation ranges between 4600 and 4850 feet. Slope ranges from 15

Figure 60. Surviving patches of trees after 2006 fire.

to 35 percent with north and west aspects.

This stand covers less than three acres. There are individual Baker cypress trees located elsewhere in the drainage but the majority of the trees a located on a small saddle below Independence valley.

Soil type – Granitic

This stand was described in 1999 (Davis et al). There are a number of fire perimeters in this area. Fire perimeters indicate the area burned in 1987 and 2006. Additional fire perimeters for the surrounding area include fires in 1917 and 2008.

Trees within the stand are intermixed with knobcone pine (*Pinus attenuata*), ponderosa pine (*Pinus ponderosa*), and white fir (*Abies concolor*). There is also a small amount of canyon live oak (*Quercus chrysolepis*) and madrone (*Arbutus menziesii*). The understory is dominated by sadler oak (*Quercus sadleriana*).

Existing conditions in the stand

Figure 61. A mix of live and dead trees after fire at Independence.

This stand was not surveyed until after the 2006 Titus Fire. Fire intensity varied throughout the stand with large areas burned at moderate to high intensity while other small areas were left untouched (Fig 60, 61).

Cores and cross-sections collected from the stand measured between 14 and 100 years, reflecting the high age diversity at this site. There were a number of patches of seedling-sized trees that measured 14 to 17 years, while the majority of the larger trees measured between 70 and 100 years.

Regeneration was high one year after the fire. In one tenth-acre plot located within moderate to high intensity burn, over 900 new seedlings were counted (Fig 62). However, seedling density was not consistent across the stand. In another plot where the burn intensity was the highest, 20 seedlings were counted within a tenth-acre area. The amount of regeneration occurring was dependent on the amount of pre-existing Baker cypress available to provide seed, and post-fire conditions such as light exposure and the presence of some remaining large snags to provide some protection to the seedlings.

Because of the fire, it was difficult to measure canopy seed storage (Fig 63). The post-fire regeneration indicates that adequate seed storage was available to restore the population. At present, there are a number of larger cone-bearing trees available to maintain a canopy seed bank for the stand. The younger cohort of trees that have germinated since the 1987 fire, are

Figure 62. new seedling one year after fire.

just beginning to produce cones. As long as no stand replacing fire occurs in the next 10 years, this stand has enough healthy individuals to restore the canopy seed bank given time.

Current Fire Conditions

In 1987, the King Titus fire burned through this stand creating patches of new growth while leaving patches of older trees. The 2006 Titus fire again burned through the stand. In 2008, the Panther fire burned around the area, but did not re-burn the area burned in 2006. In 1917, a fire burned within the watershed and while this fire is not mapped to overlap the current boundaries of the Cypress stand, the age range of the older trees suggest that this fire might have affected regeneration in the stand.

There are 490 fire starts within the fifth-field watershed, two within 1000 meters of the stand. Approximately 65 percent of these were the result of lightning strikes. Fire history at this stand shows the most consistent pattern of burns overtime as compared to the other stands.

Management Recommendations

With the number of burns occurring naturally in this area, no prescribed burns are recommended at this time. Given the location of the population within the Marble Mountain wilderness, regular fire intervals are expected to occur frequently enough that additional prescribed burning is not required. This stand should be monitored on a regular basis to assess stand health and canopy seed storage.

In 1999, the forest genetics group collected seed from approximately 14 trees in the stand. This collection contains over 33,000 seeds. This collection should be test over time to check seed viability. If necessary, future seed collections could help to ensure that adequate seed is available to restore this population, should fire return before the stand has had adequate time to mature.

VI. Future Work Needed and Ongoing

Research:

- A PhD thesis addressing genetic variation among Baker cypress populations was terminated after the tragic death of Nancy Brown. This important study is currently delayed until another student, and funding, can be identified to continue this project.
- An evaluation of temperatures required to open cypress cones is being conducted as part of a Master's thesis by Kate Milich at Humboldt State University.
- We are continuing to monitor our sampling plots established at the Mud Lake RNA in 2007. After the Moonlight Fire, we added additional plots to monitor post fire seedling survival and growth rates in 14 permanently marked plots which burned at varying intensities.
- In 2008 we started a small experiment to determine the effect of overstory cover and understory competition on Baker cypress seedling growth and survival at the Mud Lake RNA.
- The Feather River Ranger District has planned a prescribed burn for the Hollywood site of Macnab cypress. We have five years of pre-treatment data at this site and we will continue our monitoring until post treatment data can be collected.
- Further study is necessary to determine what factors are contributing to rot of Baker cypress trees and how this may affect the canopy seed storage and stand health. An evaluation of soil moisture would be an important component of this study.
- We observed diverse lichen and mistletoe species growing on Baker cypress. Additional research on lichen and mistletoe communities associated with Baker cypress, and their effect on cypress health, is needed.
- We are working with the Lassen National Forest to develop remote sensing techniques for mapping Baker cypress.

Management:

- We are currently working with the Mt. Hough Ranger District to examine the need for post-fire fuel reduction treatments within the Mud Lake RNA.
- The Lassen National Forest is planning thinning and prescribed burning treatments on the Lassen site. We are working with them to plan these treatments and monitor their effectiveness at promoting Baker cypress canopy seed storage and post-fire regeneration.
- Feasibility analysis of prescribed burning within the Hamburg site by a skilled fuels technician is needed.
- Further surveying of the Hamburg site is needed to determine the extent of the Baker cypress population there.
- Exclosures erected around seedlings at the Flounce Rock site need to be removed so as not to further inhibit growth. Creating a single large exclosure around a larger number of trees and habitat would provide protection from herbivory and allow trees to grow.

- The small size of the Flounce Rock population and the current stand conditions indicate that immediate action be taken to maintain this stand before it is extirpated. Seed should be collected from this population so that the stand could be restored in the event of extirpation.
- Seed collected from the Independence stand in 1999 should be tested over time to for viability. If necessary, future seed collections should be conducted to ensure that adequate seed is available to restore this population should fire occur before the stand has matured.

VII. Acknowledgements

This project is funded by the Joint Fire Science Program with cooperation from the USDA Forest Service. We dedicate this work to Nancy Brown, who contributed greatly to our study in the course of her PhD research on Baker cypress. She is greatly missed. We would like to thank Max Creasy for serving as co-PI on this project and giving us valuable advice and insight. We would also like to thank our field assistants Kyle Pritchard, Stephanie Blumer, Ingrid Burke and Tony Blair, as well as numerous District staff who contributed to this project. This study would not have been possible without the support of the USDA Forest Service and DOI Bureau of Land Management.

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IX. Deliverable Crosswalk Table

Deliverable	Description	Status
Website	Website describing project objectives, study sites, and results will be posted.	Internal website completed.
Data	All data collected during the first season will be provided to collaborators.	Delivered internally beginning January 2007
Annual Report	Annual report for Joint Fire Science Program Office.	Provided June 2007, June 2008.
Presentation	Presentation of results at agency and professional meeting such as the Association for Fire Ecology annual meeting.	Presented at Association for Fire Ecology Meetings, California Native Plant Society Meetings, and at Plumas and Lassen National Forests.
USFS Workshop and Field Trip	The workshop and field trip will provide a summary of information obtained and management recommendations for cypress across the study area, including field trip to several cypress sites to illustrate findings. Workshop will focus on developing management options for extant cypress occurrences.	Conducted fall of 2009.
GTR publication	Publication will synthesize results of experimental work and make management recommendations for cypress stands across the study area.	In preparation.
Final Report	Report of project findings and accomplishments will be submitted to Joint Fire Science Program Office.	
Research papers	Results will be submitted for publication in peer-reviewed journal.	Conference proceedings submitted May 2009. Additional manuscripts in preparation.