

Influence of Forest Thinning on Epicormic Shoot Growth in California Black Oak



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Following European settlement, resource extraction, and fire suppression in the past 150 years, Northern California forests have experienced a change in structure and composition and altered fire regimes, leading to compromised species composition and increased high intensity fire risk. California black oak (*Quercus kelloggii*) is one native species undergoing conifer encroachment due to a lack of fire disturbance and past logging activities. Forest thinning was used at Whiskeytown National Recreation Area to improve black oak old growth, reduce fuel loads, and restore pre-settlement conditions. Four years after thinning, the presence and height of epicormic shoot growth was measured as an indicator of thinning impacts in a treated area versus a control area. Epicormic shoots were found in a significantly greater proportion in the treated area than in the control area, but no significant difference existed between mean heights in epicormic growth in the two populations. Increased epicormic shoot growth in the treated area could indicate improved forest conditions following thinning, including increased light availability, reduced crown competition, and conditions to encourage replacement seedling growth of black oaks.

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Introduction

Forest management is a topic of concern in California following a legacy of extensive fire suppression, resource extraction through logging and mining, and impacts from human settlement dating to the late 1800's. In Northern California, this legacy has altered natural wildfire disturbance patterns. The frequency and diversity of fire intensities was greatly reduced following European settlement, leading to detrimental changes to the composition and structure of forests (Fry & Stevens, 2006). As a result, forests today often have high stand densities and large amounts of surface fuels, making them vulnerable to high intensity fire (Stephens et al., 2009, Syphard et al., 2007), and altering local plant community composition (Cocking, Varner, & Sherriff, 2012; Holmes, Veblen, Young, & Berry, 2008).

Changes to forest structure and composition have increased fire risk and also restricted the growth and vitality of some native species, including oaks (McCreary & Kerr, 2002; Rossi, 1980). California black oaks have been declining due to past fire suppression and changing species proportions within plant communities, as seen by increased competition and encroachment from conifers, which grow more quickly and overtop shade intolerant oaks. Successful young seedlings from acorn dispersal or sprouting have diminished and mature trees die without replacement (Garrison, Otahal, & Triggs, 2002; Holmes et al., 2008); Tappeiner & McDonald, 1980). Low intensity fire is a necessary disturbance needed for oak regeneration in the presence of conifers, and to lessen the buildup of forest fuels that lead to high intensity fires and oak mortality (Cocking et al., 2012; Plumb & McDonald, 1981).

In the absence of a natural fire regime, multiple approaches have been examined by land managers to reduce fuel loads and restore historic forest structure and composition, including prescribed fire (Stephens et al., 2009), thinning (Keyes, Perry, & Plummer, 2010), mastication (Bradley, Gibson, & Bunn, 2006), or a combination of these techniques. In one Northern California site, Whiskeytown National Recreation Area adopted a fire management plan to include multiple techniques

aimed at reducing fire risk and restoring pre-fire suppression and pre-logging forest conditions to best extent possible (National Park Service (NPS), 2004). In 2010, the Brandy Creek Forest Restoration Demonstration Area (Demonstration Area) was selected as an initial site to perform a small-scale stand restoration. Goals of the project included releasing present old growth large diameter oaks from competition through selective thinning of Douglas fir (*Pseudotsuga menziesii*) and small diameter understory trees while accomplishing fire management goals by reducing fuel loads (Milestone, 2010).

Following the Demonstration Area restoration, epicormic shoots were observed in the area treated by thinning. Epicormic shoots may be one of many indicators of restoration impacts on hardwood trees like black oak. Forming from the release of dormant buds on the bole in species like oak, poplar, and elm, shoots grow in response to light or stress, with genetics and hormone production also restraining or inducing shoot growth among species (Meier, Saunders, & Michler, 2012). Following changes from forest thinning, numerous epicormic shoots often form on sprouting trees like oaks due to increased light availability (Busgen & Munch, 1929; Zimmerman & Brown, 1971). Thinning or naturally caused openings and reduced competition in forest structure also allows for increased growth and expanded shape of tree canopies (Zimmerman & Brown, 1971), a desired result to promote old growth oaks, oak regeneration, and restoring pre-settlement forest characteristics in locations like Whiskeytown.

Four years after the completion of forest thinning activities in the Demonstration Area, two hypotheses are offered concerning the growth of epicormic shoots on black oak trees in a thinned treatment area versus an un-thinned control area. First, the number of black oak trees with epicormic shoots present on the bole will be greater in the treated area than in the control area. Second, the mean height of the first epicormic shoots found on the bole will be lower on trees in the treated area versus trees in the control area. Null hypotheses would reject any significant difference in oak tree growth between the treated area and the control area: no significant difference in the number of trees with

epicormic shoots in the treated area versus control area, and no significant difference in mean height to the first epicormic shoot in the treated area versus the control area.

Study Area

The study area was located within Whiskeytown National Recreation Area, a National Park Service unit in Shasta County located approximately seven miles west of Redding, California. Whiskeytown is a fire adapted landscape with hot, dry summers and cool, wet winters; the area receives an average of 60 inches of rain per year (NPS, 2004). A 2008 assessment of natural resource and watershed conditions (Golightly, Kramer, & Hamilton, 2011) concluded the vegetation composition and structure in the park had been impacted by past fire suppression and human activity such as logging, mining, and grazing in the past 150 years. Data was collected in and around the Demonstration Area, presumed to have been logged in the late 1950s and early 1960s, and deficient of wildfire for at least the past 80 years (Golightly et al., 2011; Milestone, 2010). The Demonstration Area included land adjacent to Brandy Creek Road and Shasta Bally Road ranging in elevation from 595 to 670 meters. Two areas of interest were chosen for the study, a treated and a control area, 2.1 and 3.7 hectares in size, respectively (see Figure 1). The two areas of interest were bisected by Brandy Creek Road approximately 0.4 km east of the Brandy Creek Trailhead, a popular hiking destination within the Brandy Creek watershed.

The control area was located south of Brandy Creek Road. The terrain was steep, reaching slopes up to 50 percent (Natural Resources Conservation Service (NRCS), 2014), with a north to northeast aspect. Vegetation was comprised of a relatively dense conifer-hardwood mix. Species included Douglas fir, ponderosa pine (*Pinus ponderosa*), maple (*Acer macrophyllum*), canyon live oak (*Quercus chysolepis*), and tan oak (*Lithocarpus densiflorus*) in shrub and tree form, with few incense cedar (*Calocedrus decurrens*) and sugar pine (*Pinus lambertiana*). Recent hand-thinning was evident with multiple slash piles assembled, mostly in the central and western portion of the area. Evidence of

historic logging activities were found in skid roads of varying deterioration. Soil types in the control area were Neuns very stony loam (8 to 50 percent and 50 to 80 percent slopes) and Chaix sandy loam (30 to 50 percent slopes).



Figure 1. Map of the treatment and control areas within Whiskeytown National Recreation Area.

The treated area was located north of Brandy Creek Road, with Brandy Creek Trail bisecting the area in an east-west direction following gentler terrain. Slope was relatively flat to moderately steep, ranging from 8 to 50 percent slopes (NRCS, 2014), but generally less than 30 percent in areas thinned during a restoration effort started in 2010. Aspect was north to northeast. Vegetation included a conifer-hardwood mix similar to the control area but having a higher frequency of hardwoods including black oak, maple, and canyon live oak, with fewer pines than the control area. Vegetation was less dense as a result of forest thinning, with spaces between trees typically 30 meters or more, and an observable decrease in the amount of canopy cover compared to the control area. Slash piles and recent burn piles show the continued effort to reduce fuel loads in the area. The majority soil type was Neuns very stony loam (8 to 50 percent slopes).

Methods

Data was collected in the Demonstration Area across a two day period in mid-October. Twenty-five trees were sampled in both the treated and control areas. Data collected for each oak included

general tree measurements: height, diameter at breast height (DBH), an estimate of the degree of tree lean (potentially influencing the accuracy of tree height measurements) and tree damage such as fire scorch, damage to the trunk, or damage to major limbs. Data to test hypotheses included the presence or absence of epicormic shoots, height to the lowest epicormic shoot, and the number of epicormic shoots found at the lowest height. Tree height was measured using a Laser Technology TruPulse 200 laser range finder. Height to the first epicormic shoot was measured using a TruPulse range finder, or a tape measure if located at a height within reach, generally below 1.5 meters. Epicormic shoots were considered valid if they were located on the main bole, and appeared to have a diameter less than three centimeters. DBH was measured on the upslope side of each tree with a standard loggers tape. Tree lean was estimated based on a 0-90 degree scale, with 0 being upright and 90 being parallel with ground level.

A series of 25 randomly selected coordinate pairs were chosen in both the treated and control areas as sample points (see Appendix I). Coordinates were selected by placing points across each study area using aerial imagery provided by Google Earth, which shows overall dense canopy cover at the site but no indication of tree species that could bias coordinate selection. After locating the coordinate site using a Garmin Map 60 GPS, the nearest black oak tree was selected and measured (see Appendix II for sample tree locations). This method was successful in the treatment area, but was modified while collecting data in the control area, as noted later in the discussion.

The planned sampling method was adapted during field work in the control area. The density of black oak trees within the control area made finding the nearest oak to random sample points difficult, with distances to the nearest tree in the first points sampled exceeding 70 meters. Also, hand-thinning as a continuation of the restoration work in the Brandy Creek demonstration area was greater than anticipated after the initial site visit. Due to low tree density and hand-thinning treatments, an alternative grid system was developed using the extent of the control area and compass bearings.

Beginning in the southeastern extent of the control area, a 315° azimuth (northwest) was set and followed. Oak trees within 15-20 meters of the bearing were selected and measured. Once the southwestern extent of the area was reached, the grid pattern was continued by pacing north and turning to follow a 135° azimuth (southeast). The original western extent of the control area was also extended in order to collect 25 samples that did not fall in proximity with hand-thinning activities.

One sample tree was removed from each of the sample populations. In the treated area, TA-002 was the nearest oak to the random sample point and was measured, but fell outside the restoration area and was discarded. In the control area, CA-002 was also discarded as the small size (DBH < 5 inches) was considered an outlier to the rest of the samples collected in both the treated and control areas. In each area, one extra tree was sampled to achieve a sample of 25; from the last tree sampling point, a bearing was set to leave the sample area and the first black oak encountered in the path was chosen.

Results

A greater number of black oak trees in the treated area ($N = 25$) had epicormic shoots than trees in the control area ($N = 25$), as seen in Table 1. Twenty-four trees in the treated area (96%) had at least one epicormic shoot, compared to 16 trees in the control area (65%). To determine if a significant difference existed between these two groups, a two-sample z-test for proportions was performed, with alpha set at .05. Results of the test showed a significantly larger proportion of trees had epicormic shoots in the treated area than the control area, $z = 2.83$, $p < .05$.

Table 1. Trees observed with at least one epicormic shoot in the treated area versus the control area.

	<i>N</i>	Trees with Epicormic Shoots	% of Sample Population
Treated Area	25	24	96
Control Area	25	16	65

From the sample trees having epicormic shoots, mean height to the first shoot was slightly higher in the treated area ($N = 25$, $M = 3.35$) than the control area ($N = 16$, $M = 3.17$), as seen in Table 2. The results of a one-tailed independent samples t -test was conducted to determine if the mean height to the first epicormic shoot was significantly different between the two groups, with alpha set at .05. The t -test revealed no significant difference in mean height to the first epicormic shoot in the treated area ($M = 3.35$, $SD = 2.50$) versus the control area ($M = 3.17$, $SD = 2.04$), $t(36) = 1.69$, $p = .40$.

Table 2. Sample, mean, and standard deviation of tree height to first epicormic shoot (m) in the treated versus the control area.

	<i>N</i>	<i>M</i>	<i>SD</i>
Treated Area	24	3.35	2.50
Control Area	16	3.17	2.04

Discussion

The results support one of two hypotheses concerning the growth of epicormic shoots on black oak trees following thinning restoration. The first hypothesis predicted a greater number of trees would have epicormic shoots present on the bole in the treated area than the control area. The first hypothesis was supported by the data, with a significant proportion of trees in the treated area (96%) having epicormic shoots compared to only 65% of trees in the control area. Concerning the number of trees having epicormic shoots present, we may reject the null hypothesis and accept a significant difference between the two sample populations.

The second hypothesis predicted the height to the first epicormic shoot would be lower in the treated area than in the control area, but was not supported by the data. Mean height to the first epicormic shoot was slightly lower in the treated area than in the control area. The difference between mean heights was not significant, however, as shown by the t -test results. From this, we must accept the

null hypothesis that no significant difference exists between mean heights to the first epicormic shoot found in the two sample populations.

The results suggest that the presence of epicormic shoots on black oaks may be an indicator of forest thinning impacts, while shoot height on the bole may not. The larger proportion of epicormic shoots in the treatment area versus the control area could indicate a positive impact of forest thinning on present and future black oak growth. The release of epicormic shoots indicate increased light availability and reduced crown competition, which would support restoration goals of promoting old growth black oaks and encouraging replacement of mature trees by allowing successful oak seedling development. In lieu of natural disturbance from fire, these restoration efforts may be a successful pathway to re-establishing past forest conditions.

Future studies examining epicormic shoots could include increasing the temporal range within the Demonstration Area, measuring black oak tree characteristics in future years to determine if any change in proportions of epicormic growth between the sample populations occurred. One recommendation for further study would include finding a better representative area for a control sample, as hand thinning in and around the Demonstration Area continues to reduce overall stand density in the current control area. Further opportunity will be available to replicate this study in another location within the park as well, as a similar forest restoration project was completed in the Boulder Creek watershed of Whiskeytown National Recreation Area in the summer of 2014.

The measurement of epicormic shoots is one of many ways to examine change following forest restoration projects. The current trend sees land managers pursuing various treatment methods to restore and protect forests from undesirable changes due to past human influences. Treatment methods should aim to achieve necessary goals based on the needs of the system, such as the need to reduce fuel loads, restore pre-settlement conditions, or encourage growth to re-establish past species composition as seen here. Past human activities like fire suppression and resource extraction have not

only impacted the vitality and historic composition of forests, they also threaten overall forest health and human safety as the threat of catastrophic wildfire increases. The development of methods to evaluate change following restoration and treatment success rates are an essential component of overall forest restoration goals.

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Appendix I

Pre-selected coordinate pairs for random sampling points in the Control Area and Treated Area.

<i>Control Area</i>			<i>Treated Area</i>		
Tree ID	Latitude	Longitude	Tree ID	Latitude	Longitude
CA-001	40.596750	-122.595994	TA-001	40.598170	-122.597797
CA-002	40.596436	-122.595904	TA-002	40.598201	-122.596163
CA-003	40.596491	-122.596440	TA-003	40.597897	-122.595775
CA-004	40.596473	-122.596953	TA-004	40.597574	-122.595705
CA-005	40.596763	-122.597622	TA-005	40.597556	-122.595738
CA-006	40.596877	-122.598054	TA-006	40.597711	-122.596066
CA-007	40.596756	-122.598491	TA-007	40.597064	-122.596837
CA-008	40.596484	-122.598432	TA-008	40.597865	-122.597127
CA-009	40.596359	-122.598126	TA-009	40.598015	-122.596244
CA-010	40.596442	-122.597629	TA-010	40.597964	-122.597059
CA-011	40.596365	-122.597296	TA-011	40.597351	-122.596864
CA-012	40.596272	-122.596988	TA-012	40.597839	-122.597056
CA-013	40.596320	-122.596604	TA-013	40.597844	-122.597321
CA-014	40.596278	-122.596176	TA-014	40.597611	-122.597556
CA-015	40.596198	-122.595744	TA-015	40.597816	-122.597636
CA-016	40.596055	-122.596111	TA-016	40.597544	-122.597787
CA-017	40.595866	-122.595920	TA-017	40.597439	-122.597740
CA-018	40.595616	-122.595928	TA-018	40.597472	-122.598133
CA-019	40.595718	-122.596274	TA-019	40.597286	-122.598375
CA-020	40.595891	-122.596361	TA-020	40.597744	-122.598232
CA-021	40.596074	-122.596599	TA-021	40.597845	-122.597873
CA-022	40.596030	-122.596935	TA-022	40.597839	-122.597546
CA-023	40.596129	-122.597231	TA-023	40.598159	-122.598953
CA-024	40.596223	-122.597574	TA-024	40.597627	-122.598866
CA-025	40.596197	-122.597945	TA-025	40.598021	-122.597863

Appendix II

Field-collected waypoints for sample trees in the Control Area and Treated Area.†

<i>Control Area</i>			<i>Treated Area</i>		
Tree ID	Latitude	Longitude	Tree ID	Latitude	Longitude
CA-001	40.596750	-122.595994	TA-001	40.598170	-122.597797
CA-002*	40.596436	-122.595904	TA-002*	40.598201	-122.596163
CA-003	40.596491	-122.596440	TA-003	40.597897	-122.595775
CA-004	40.596473	-122.596953	TA-004	40.597574	-122.595705
CA-005	40.596763	-122.597622	TA-005	40.597556	-122.595738
CA-006	40.596877	-122.598054	TA-006	40.597711	-122.596066
CA-007	40.596756	-122.598491	TA-007	40.597064	-122.596837
CA-008	40.596484	-122.598432	TA-008	40.597865	-122.597127
CA-009	40.596359	-122.598126	TA-009	40.598015	-122.596244
CA-010	40.596442	-122.597629	TA-010	40.597964	-122.597059
CA-011	40.596365	-122.597296	TA-011	40.597351	-122.596864
CA-012	40.596272	-122.596988	TA-012	40.597839	-122.597056
CA-013	40.596320	-122.596604	TA-013	40.597844	-122.597321
CA-014	40.596278	-122.596176	TA-014	40.597611	-122.597556
CA-015	40.596198	-122.595744	TA-015	40.597816	-122.597636
CA-016	40.596055	-122.596111	TA-016	40.597544	-122.597787
CA-017	40.595866	-122.595920	TA-017	40.597439	-122.597740
CA-018	40.595616	-122.595928	TA-018	40.597472	-122.598133
CA-019	40.595718	-122.596274	TA-019	40.597286	-122.598375
CA-020	40.595891	-122.596361	TA-020	40.597744	-122.598232
CA-021	40.596074	-122.596599	TA-021	40.597845	-122.597873
CA-022	40.596030	-122.596935	TA-022	40.597839	-122.597546
CA-023	40.596129	-122.597231	TA-023	40.598159	-122.598953
CA-024	40.596223	-122.597574	TA-024	40.597627	-122.598866
CA-025	40.596197	-122.597945	TA-025	40.598021	-122.597863
CA-026	40.596156	-122.598335	TA-026	40.597617	-122.597949

† Due to GPS limitations and satellite conditions, error rates for tree waypoints were often high, ranging from ± 35 up to ± 100 feet.

* CA-002 was determined to be an outlier because of its small size (DBH < 5 inches).

* TA-002 was determined to be an outlier as it fell outside of the treatment area.