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Assessment of Tree Attributes and Understory Vegetation Composition Six Years Post-thinning in Redwood National Park (Northern CA, USA)

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Abstract

Coastal redwoods (*Sequoia sempervirens)* are a resilient tree species that once dominated coastal ecosystems. However, redwood forests have experienced numerous impacts compromising their health and vigor, which has led to greater competition from other tree species. Foresters and Ecologists are utilizing novel restoration strategies to conserve and recover redwood forests. This project's objective was to assess tree attributes and understory composition six years after a restoration thinning treatment. The study took place in Redwood National Park in Orick, California along Holter Ridge Road at a site named Middle Fork Lost Man Creek. In 2015, a student capstone group from Humboldt State University collected data for three plots before and immediately after a thinning treatment. Six years later (2021), our capstone group resampled the data in these plots and added tree height and understory vegetation parameters. Results found that total basal area/acre increased from 205.4 in 2015 (post-thinning) to 215.0 in 2021 and the quadratic mean diameter increased from 17.5 inches in 2015 (post-thinning) to 18.9 inches in 2021. This project can serve as an example for future treatment in similar ecosystems and can potentially assist the recovery of secondary growth forests, while also assisting in connecting sections of Redwood National Park to promote redwood dominance.

Introduction

The coastal redwood (*Sequoia sempervirens)* forests that once dominated a narrow band along the Pacific Coast of California and southern Oregon, have a long history of indigenous culture, land ownership, and logging. Prior to European and Spanish settlement, the land of the redwoods was home to various Native tribes along the coast, including the Yurok Tribe (Save the Redwoods League, 2020). Redwoods were and continue to be part of indigenous and spiritual life, providing supplies to build homes, canoes and perform ceremonies (Sawyer et al., 1999). Starting in 1916, the California Redwood Association was organized to promote redwood products (Save the Redwoods League, 2020). Shortly after in 1918, Save the Redwoods League was founded and later acquired previously logged stands and pursued conservation efforts for the remaining redwood forests (Save the Redwoods League, 2020).

Few of the ancient giants characterized as old-growth redwoods remain today. The California North Coast coniferous forest habitat was extensively logged in the 20th century, leading to immense soil erosion allowing invasive species to take root (Fritschle, 2009). Nevertheless, redwoods are a resilient species and over time, new sprouts reoccupy bare land and establish themselves into secondary-growth redwood forests. As a result of the clear cuts in the mid-20th century, the new sprouts had all the sunlight they needed to grow and reproduce into immensely dense stands, producing, “deficits in composition, low tree vigor, homogeneous structure, and little biodiversity” (Teraoka, 2012). Today foresters treat, thin and manage dense forest stands to be healthy and full of biodiversity (Teraoka, 2011). Stand complexity and biodiversity of redwood forests has increased after the application of restoration treatments (Teraoka 2011).

Currently, about 45% of redwood forests in the northern coast of California are located within Redwood National Park. In 1968, Redwood National Park was created for the protection of old growth forest and management of second-growth forests (Teraoka, 2011). Ten years later after the Park's expansion, silviculture practices were used as a restoration tool (Teraoka, 2012). Over 50,000 acres of second-growth forest resides in Redwood National Park (Coast Redwoods, 2020). Foresters take active roles in thinning dense young-growth stands to promote diameter growth, greater crown ratio, increased species composition and regeneration. If left unmanaged, the threshold for diversity among individual trees, understory vegetation, as well as the stand's overall health will be significantly limited (Dagley, 2018).

Thinning treatments have been at the forefront of restorative methods used by the foresters at Redwood National Park. A previous example of forest thinning conducted in Redwood National Park is the "Whiskey Forty Forest Restoration Study," where low thinning, the removal of trees in the lower crown classes to benefit trees in the upper crown classes was used on highly dense stands to evaluate the treatment as a restoration tool for similar stand conditions (Teraoka, 2011). The Whiskey Forty Forest Restoration Study showed that residual trees responded well (Teraoka, 2011). There was a significant increase in ground vegetation diversity, yet the overstory composition was unaffected, as Douglas-fir continued to dominate because thinning intensities were either too conservative or too much redwood was removed (Teraoka, 2011). This same objective of selective thinning applies to our area of study where dense stands once stood, but where a more open canopy allows new growth to take hold.

Our objective for the six-year post-thinning monitoring is to compare our findings in the same plots with the data collected in 2015 in order to examine any changes that have occurred over time and determine any signs of growth release. Gaps and heavily thinned areas tend to have greater abundance of early seral shrubs and herbs (Ares, 2009). Our assessment will indicate if opening up canopy cover and creating gaps in dense redwood stands via thinning operations can help the health and growth in the standing trees as well as the regeneration of understory vegetation.

Methods

Site Description

The project area is located in Humboldt and Del Norte Counties in northern California. This area is known for having a Mediterranean climate with an average precipitation of 65-90 inches annually (USDA NRCS). The Middle Fork Lost Man Creek project site is located within Redwood National Park, having a long history of timber harvesting and more recently thinned plots of second growth forest. Positioned on a ridge known as Holter Ridge, the Middle Fork Lost Man Creek can be accessed via Bald Hills Road (Figure 1). The site is predominantly a conifer stand with an understory composed of mainly herbaceous and shrubby vegetation mixed with slash.

Figure 1. Redwood National and State Parks (green shaded area) and the project area, Middle Fork Lost Man Creek within the park (red shaded area) (Source: Trevitt et al., 2015).

Middle Fork Lost Man Creek Project Background

One of the main objectives for the Middle Fork Lost Man Creek project site was to create thinning units throughout the project area to resemble a secondary growth redwood forest (Chittick, 2007). The thinning treatment to the Middle Fork Lost Man Creek area occurred in 2015 at an elevation of 1,890 ft, where the initial low thinning prescriptions were implemented (Figure 2). Three monitoring plots adjacent to each other were established shortly after the thinning treatment. Specifically, plot one is the most western facing plot (41º 18' 38" N, 123º 57' 28" W), plot two lies directly between the first and third plot (41º 18' 38" N, 123º 57' 27" W), and plot three is positioned closest to Holter Ridge Road (41º 18' 38" N, 123º 57' 25" W) (Figure 2). Our study aimed to reassess the trees and understory attributes six years post-thinning.

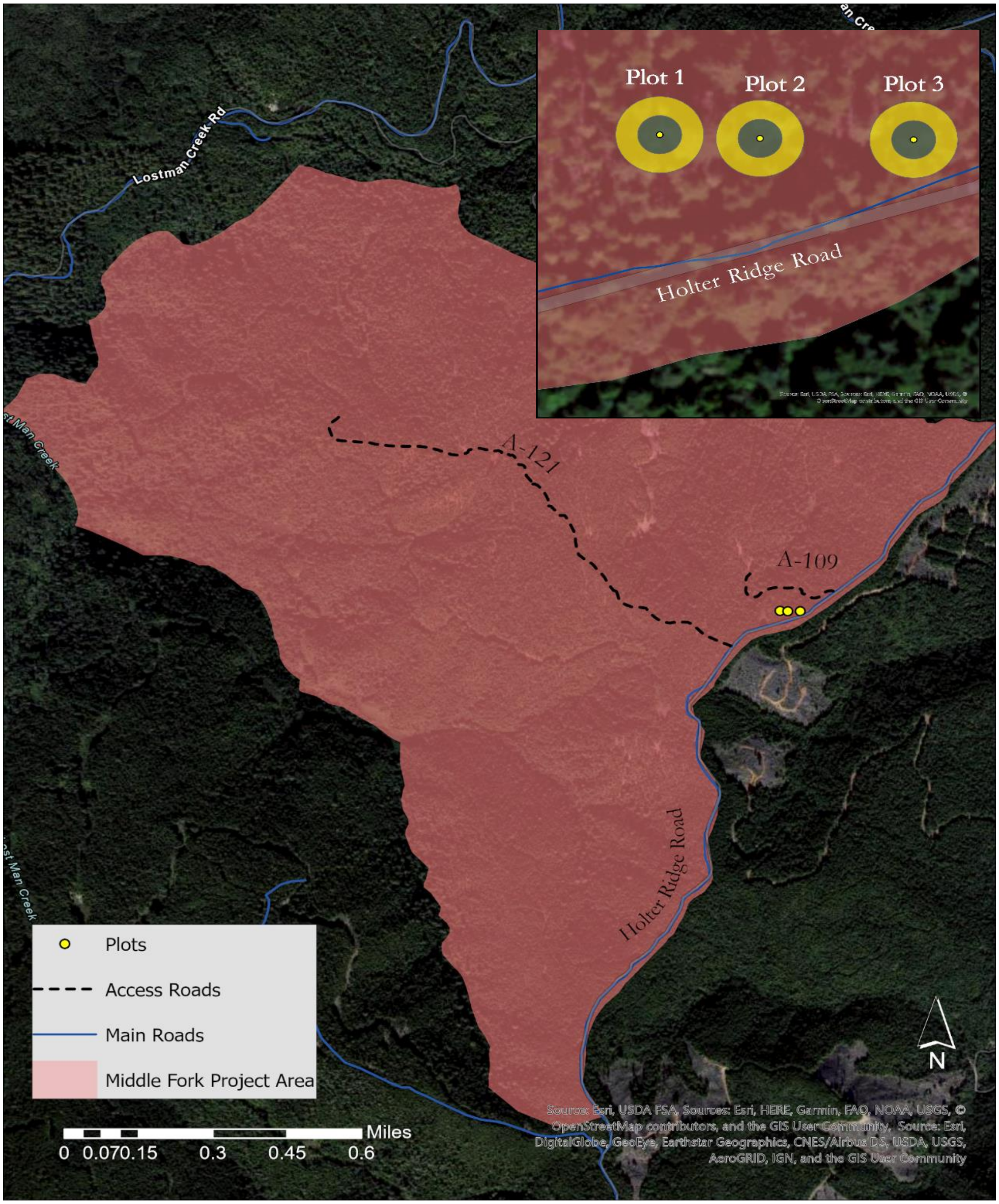

Figure 2: Locator map of the three monitoring sites at Holter Ridge Road in the Middle Fork Lost Man Creek Project area and inset map of the 1/10 acre plot (shaded yellow) and 1/40 acre nested plot (shaded grey) structure, at plot center (yellow dots). (Cartographers: S. Giraldo, V. Andrews, and M. Vongsa, 2021).

Field Methods

The previous data collected in 2015 were used to compare with our 2021 monitoring assessment. Both data collection periods aided in determining whether the thinning prescription applied to the project site assisted in promoting growth for redwoods. In 2015, three monitoring plots were designed using random stratification sampling protocols in the Middle Fork Lost Man Creek Project area.

The sample design was constructed to take measurements of trees with a dbh >10.6 inches in three 1/10th acre circular plots (Figure 2). A 1/40th acre plot was nested within each of the 1/10th acre plots, sharing the same plot center to sample trees with a dbh between 4.5-10.5 inches (Figure 2). Data were collected in a sequence of three days (February 27, March 6, and March 14, 2021), focusing on one plot per day. Collection of tree data was organized by splitting each plot into four sections: NE, NW, SE, and SW facing quadrants, and systematically gathering information within each quadrant in a clockwise order.

The tree dbh, crown ratio, and observed damage data collected in 2015 by a student capstone group from Humboldt State University was re-collected in the same plots by our group in 2021. In addition to these parameters, tree height was recorded with a laser hypsometer for all tagged trees. Visual observations and plant identification were also noted to determine average understory cover of vegetative species and the total count of individual tree seedlings within the 1/40th acre nested plot. Supplemental data for tree ingrowths were collected, tagged, and documented. Trees within the three 1/10th acre plots whose diameters have grown within the last six-years to meet the minimum dbh range were categorized as ingrowth.

New nails and identification tags were added to ingrowth trees and red paint was applied for ease of recognition. The retagging of aluminum numbered tags into the previously recorded trees and reapplication of red paint was necessary as tree growth had overwhelmed the majority of the initially inserted nails. At each plot center, photos were taken in each cardinal direction and directly above to capture canopy cover for comparison of past photos from 2015 (Appendix I).

Results

The thinning treatment conducted six years ago in 2015 resulted in an increase in tree diameter growth. Douglas-fir (*Pseudotsuga menziesii*), redwood, and tanoak (*Notholithocarpus densiflorus*) remain the dominant tree species in the thinned plots. In comparison to before and immediately after thinning, the quadratic mean diameter (QMD), characterized as the average measured tree diameter in a stand, had an overall 1.4 inch increase (an 8% change), six-years after the initial thinning (Table 1). Each tree species' total QMD increased at every stage of the thinning process, representing considerable diameter growth of the stand since prior to the thinning treatment.

Table 1. *Forest conditions before and after thinning in 2015, expressed in number of trees per acre, basal area per acre, and quadratic mean diameter or QMD (in).*

	Trees/acre		Basal Area/acre		QMD (in)
	Mean	% Composition	Mean	% Composition	
Before Thinning (2015)					
Douglas-fir	206.7	49.2	184.5	51.9	12.8
Redwood	103.3	24.6	134.6	37.9	15.5
Tan Oak	110.0	26.2	36.3	10.2	7.8
Total	420.0	-	355.4	-	12.5
After Thinning (2015)					
Douglas-fir	50.0	40.5	80.4	39.1	17.2
Redwood	53.3	43.2	114.8	55.9	19.9
Tan Oak	20.0	16.2	10.2	5.0	9.7
Total	123.3	-	205.4	-	17.5
Six-years After Thinning (2021)					
Douglas-fir	50.0	45.5	91.8	42.7	18.3
Redwood	40.0	36.4	111.8	52.0	22.6
Tan Oak	20.0	18.2	11.4	5.3	10.2
Total	110.0	-	215.0	-	18.9

An increase of total basal area per acre, or otherwise known as the average amount of an area occupied by tree stems, was also measured six years after the thinning treatment (Table 1). Our results showed a decrease in redwoods for both mean and percent composition in terms of trees per acre and basal area per acre (Table 1). The number of redwoods per acre decreased from 53.3 to 40, while the composition decreased from 43.2 to 36.4. Redwood basal area decreased from 114.8 ft^2 to 111.8 ft^2 while the composition decreased from 55.9% to 52.0%.

The conditions prior to the thinning show the initial diameter classes in the stand (Figure 3A) for each of the three dominant species. Immediately after the thinning treatment, the dominant species shifted from Douglas-fir and tanoak to redwood (Figure 3B). Generally, the thinning treatment concentrated on removing species trees below the 18 inch diameter class. Additionally, the thinning treatment removed all trees that were in the diameter class <6 inches (Figure 3A and 3B). The largest redwood diameter classes pre-thinning and post-thinning maintained the same throughout the study. Results also show that between the 2015 thinning treatment and 2021 post monitoring, the three largest redwood diameter classes were bumped up from 32 to 34 inches and 44 to 46 inches, while the 40 inch diameter class remained the same (Figure 3B and 3C). However, due to the tree mortality observed in redwood in the six year post-thinning, the dominant species returned back to Douglas-fir. Each species shows growth with trees moving into higher diameter classes over time; except in the decrease observed in trees per acre of the 10 inch diameter class for redwoods, also attributed to the tree mortality (Figure 3B and 3C).

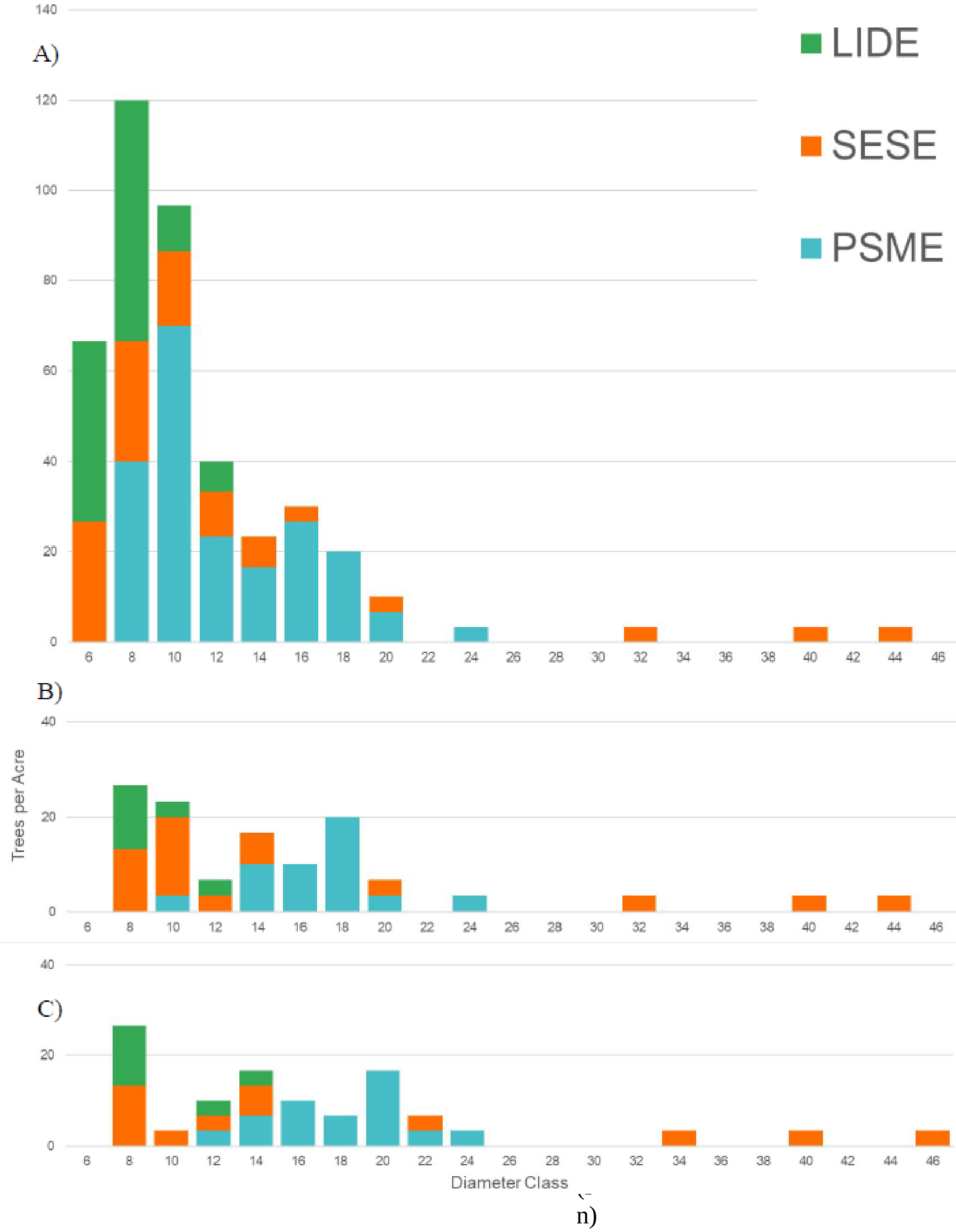

Figure 3. Tree diameter distributions, stacked by species, for before thinning (2015, A), immediately after thinning (2015, B), and six years after thinning (2021, C).

Species heights across diameter ranges have started to stratify in terms of species vertical canopy positions (Figure 4). All trees generally plateau off in height, in which a logarithmic regression best explains the variability. Redwoods had the widest range of heights compared to tanoak and Douglas-fir, while tanoaks had a smaller range of heights than those of Douglas-fir and redwood. When comparing Douglas-fir to redwoods in this analysis, Douglas-fir was the most dominant tree species in terms of height, but had a smaller range of diameter classes. This analysis also illustrates three dominant redwood trees, with one being present in each of the three plots further showing an equal distribution. However, two shorter redwood tree outliers were observed, both having broken tops.

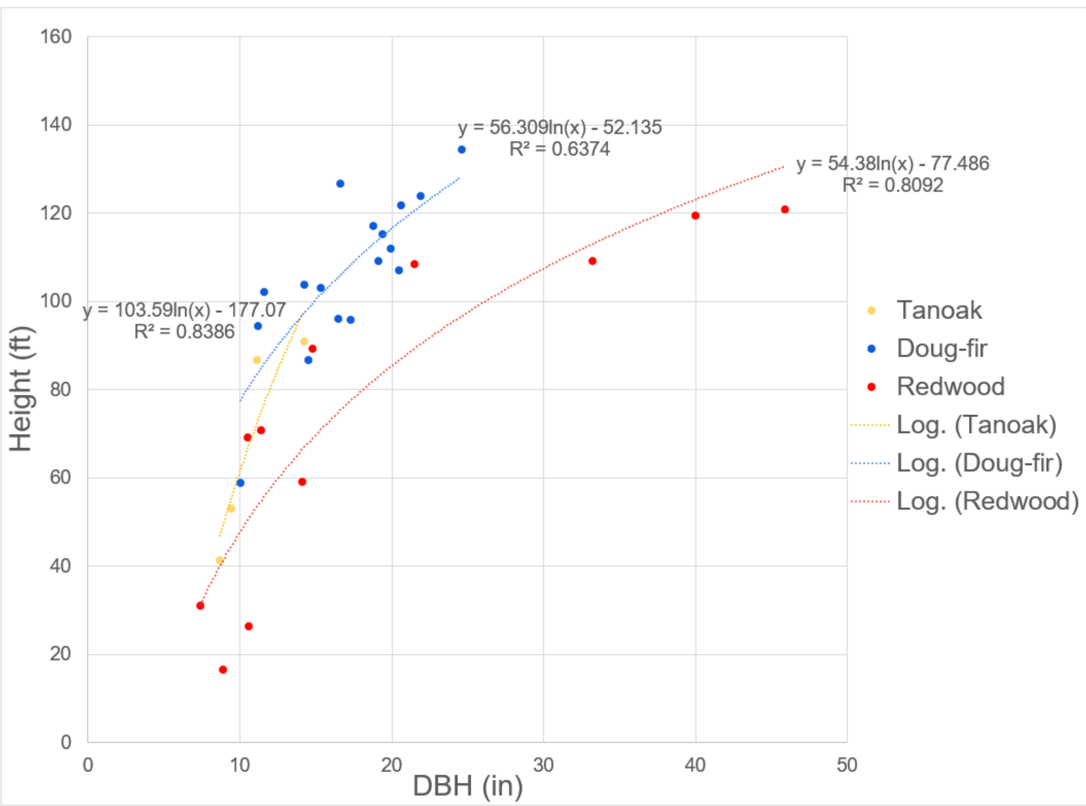

Figure 4. The tree height in relation to diameter at breast height (DBH) of the three dominant tree species (tanoak, Douglas fir, redwood) as observed in the six years post thinning assessment. These data points represent the canopy occupancy throughout all plots alongside logarithmic equations associated with their distribution.

The data collected on ingrowth shows new tree records that now meet the minimum diameter requirements for the sample design (Figure 5). The majority of the ingrowth by trees per acre was Douglas-fir, followed by redwood and then tanoak. The total mean of ingrowths was 46.7 trees per acre, while the total mean for basal area per acre was 18.0. Based on our findings, the diameter class 10 showed the highest amount of trees per acre which included all three species. At least one ingrowth tree was found in each plot.

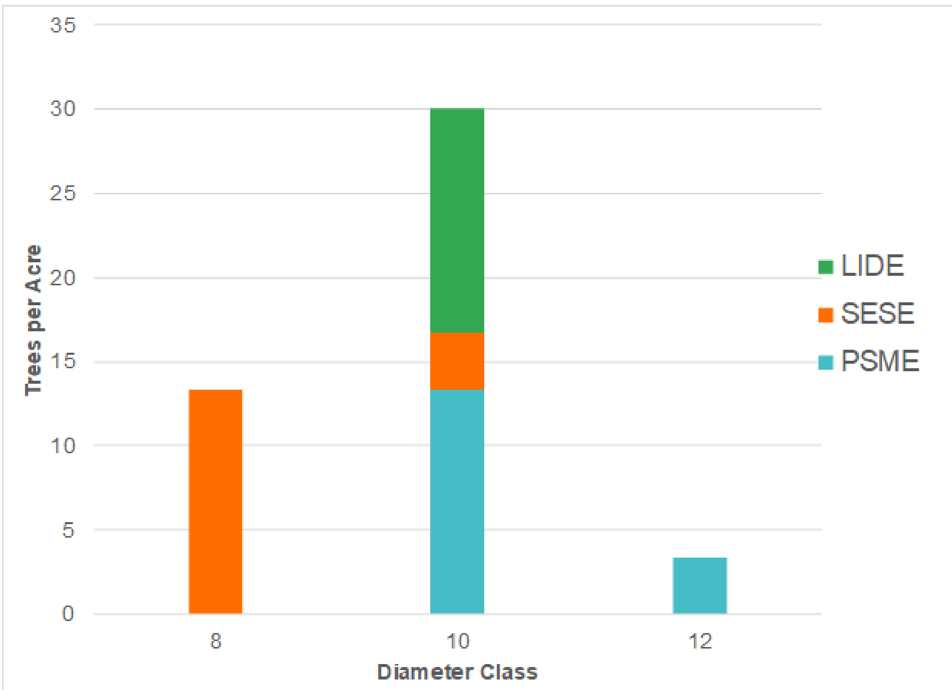

Figure 5. Diameter distribution of ingrowth trees stacked by species six years after thinning. TSHE: Western Hemlock, SESE: redwood, LIDE: tanoak.

By comparing our 2021 data with the 2015 data collected from the same three plots, we calculated overall percent reduction in basal area per plot with the number of recorded seedlings (Figure 6). Plot two had the highest reduction in basal area and the number of seedlings observed. Additionally, we found that the average seedlings per acre were predominantly redwood with a value of 65.7 inches (Figure 7). Curiously, western hemlock (*Tsuga heterophylla*) had the lowest value at 24.7 inches, and tanoak had a value of 45 inches (Figure 7).

There were no observed Douglas-fir seedlings, likely due to the fact that Douglas-fir is a shade intolerant species and was out competed by the other shade tolerant species present. Overall, the data shows that the reduction in basal area was positively correlated to the number of seedlings found in the plots (Figure 6).

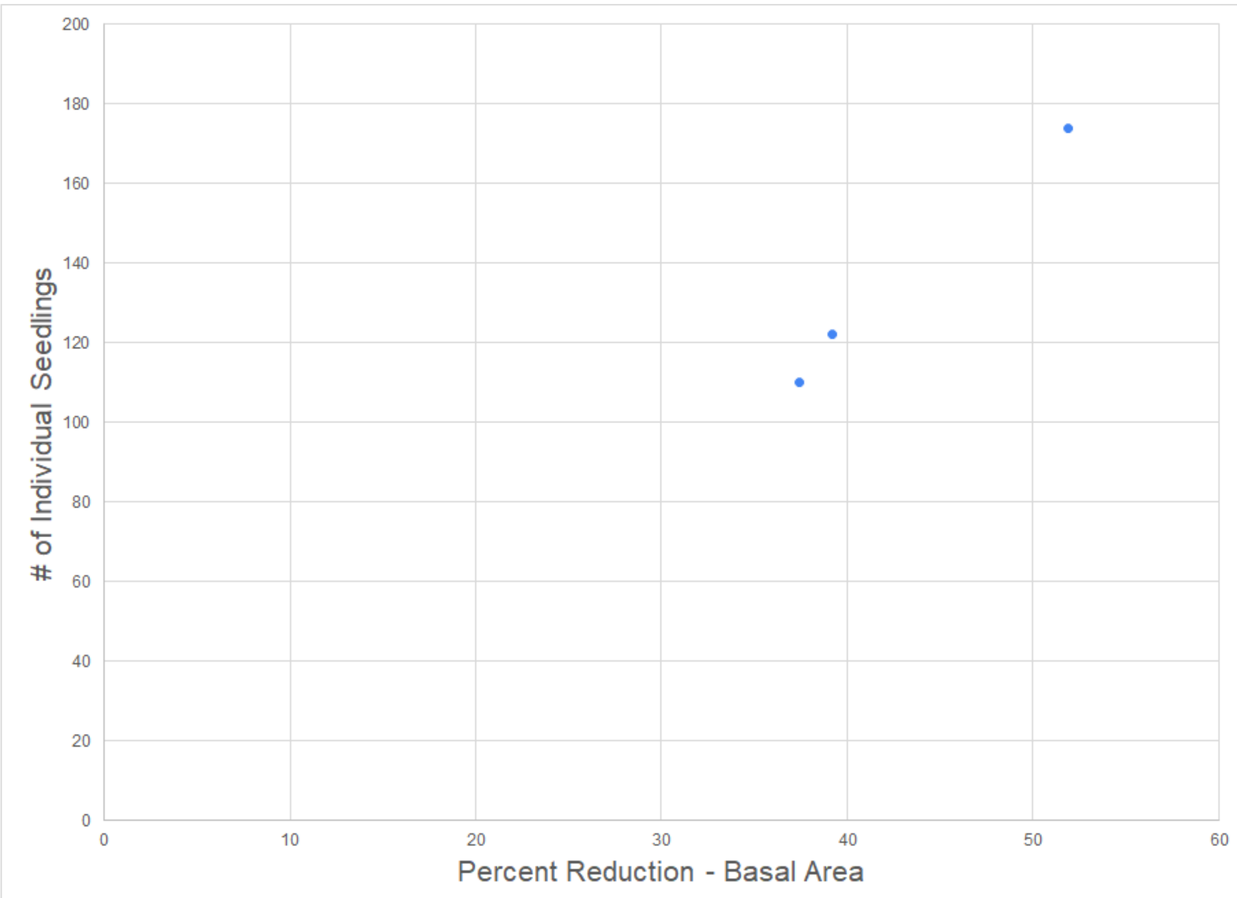

Figure 6. Each of the three plots' standing when comparing the count of individual seedlings regenerated in relation to the overall percent reduction in basal area six-years after the initial thinning in the Middle Fork Lost Man Creek project.

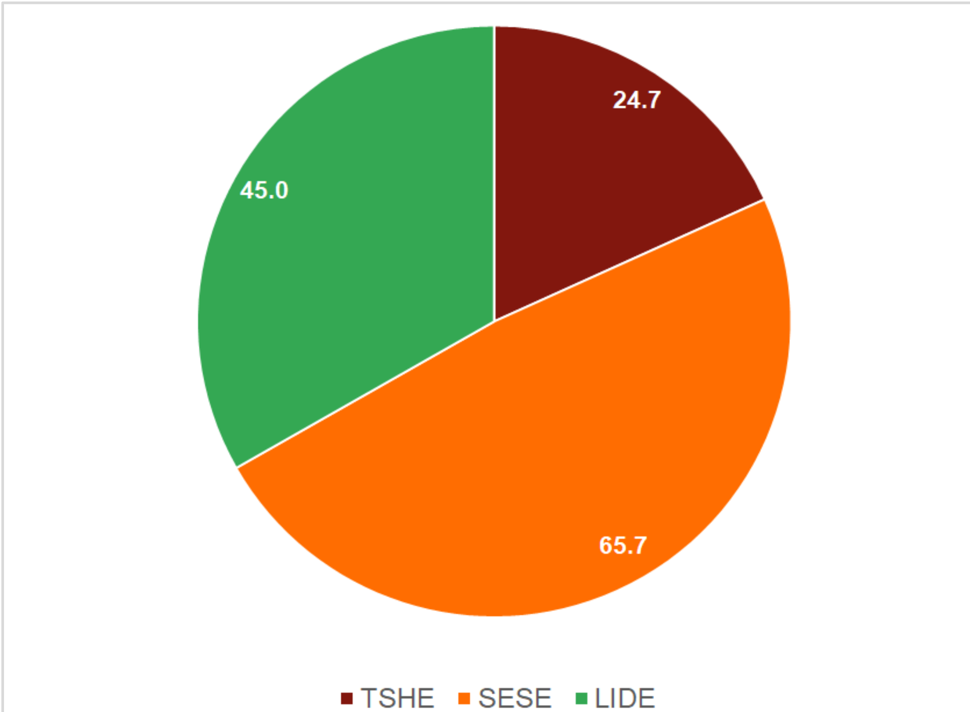

Figure 7. Species composition of seedlings (height <4.5ft) per acre as observed six years after thinning. TSHE: Western Hemlock, SESE: redwood, LIDE: tanoak.

Initiation of understory vegetation including tree regeneration (seedlings), herbs and shrubs were recorded six-years after thinning. Redwood (25 seedling per acre) and hemlock (66 seedlings per acre) were the only two conifers species observed. Tanoak (45 seedlings per acre) was the only hardwood species observed. Across all three plots, the herbaceous plant modesty (*Whipplea modesta*) was the most common species in the understory with an average cover of 32.3% per acre (Figure 8). The second-most observed species was the shrub evergreen huckleberry (*Vaccinium ovatum*) with an average cover of 19.7%. Lastly, the herb rattlesnake plantain (*Goodyera oblongifolia*) was the least species observed with an average cover of 0.3%. Modesty, evergreen huckleberry, redwood violet (*Viola sempervirens)*, Douglas' iris (*Iris douglasiana*), and salal (*Gaultheria shallon)* were ubiquitous in all plots.

Table 2: *Species list of regenerated flora and seedlings identified in the understory vegetation in the three plots, six years after thinning operation in the Middle Fork Lost Man Creek project.*

Scientific Name	Common Name	Cover Type
Sequoia sempervirens	redwood	Conifer
Tsuga heterophylla	western hemlock	Conifer
Lithocarpus densiflorus	tanoak	Hardwood
Whipplea modesta	modesty	Herb
Viola sempervirens	redwood violet	Herb
Iris douglasiana	Douglas' iris	Herb
Goodyera oblongifolia	rattlesnake plantain	Herb
Polystichum munitum	western sword fern	Fern
Vaccinium ovatum	evergreen huckleberry	Shrub
Rhododendron macrophyllum	Pacific rhododendron	Shrub
Gaultheria shallon	salal	Shrub
Berberis nervosa	Oregon grape	Shrub
Vaccinium parvifolium	red huckleberry	Shrub

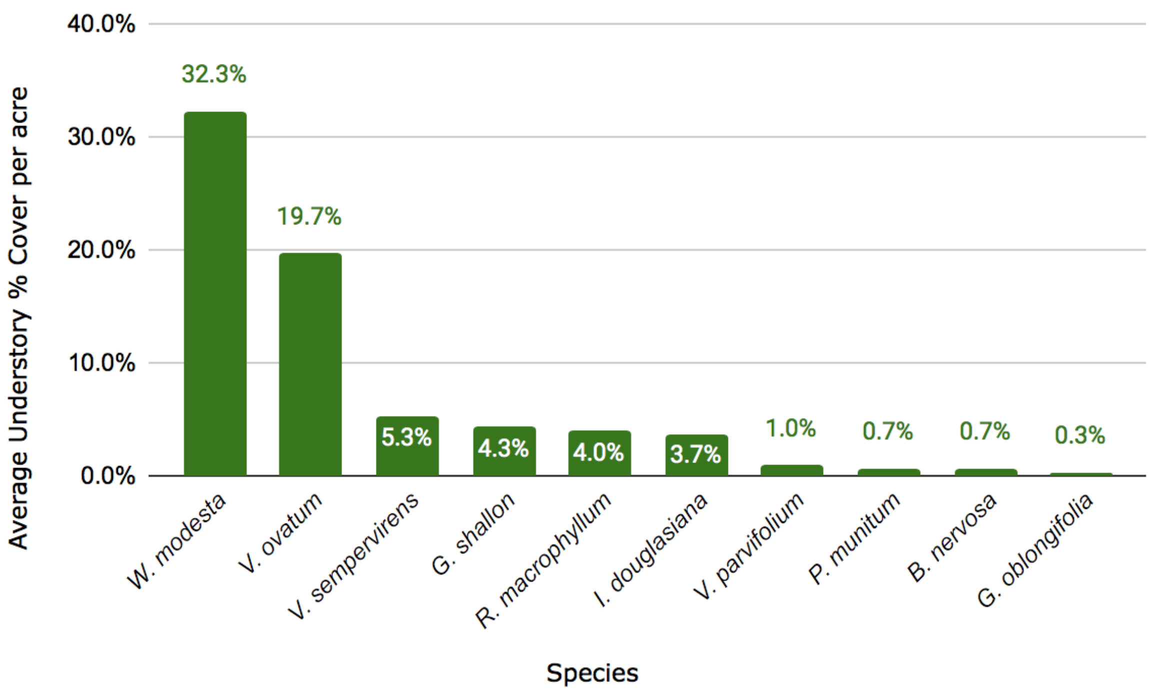

Figure 8: Average percent cover per acre of identified understory species for all plots.

Discussion

Our study found a positive relationship between the thinning treatment and its effects on basal area per acre, tree diameter (QMD), ground vegetation growth, and species diversity. Previous studies have found that thinning is an effective means of enhancing old forest development by accelerating tree growth, modifying species composition, and increasing stand-level variability (O'Hara, 2010). Despite our results showing a positive correlation between the variables analyzed, we had a relatively small sample size that was potentially not representative of the treatments at the Middle Fork Lost Man Creek Project.

One outlier that influenced our data was a fallen redwood that was originally standing after the thinning in 2015. By losing this one tree, it greatly affected our stand data because we were expecting redwood to be the most dominant species in terms of growth. The average diameter class in correlation to trees per acre, was lower than expected when analyzing redwoods in the six-year post thinning treatment data. It also contributed to an overall decrease in total trees per acre from 123.3 after the thinning to a mean of 110 six years later (Table 1). This outlier brought the basal area per acre average significantly below a desirable threshold by losing 13.3 trees per acre. Even though there was a decrease in redwoods trees per acre, there were several new sprouts observed growing from that fallen tree (Appendix I, Plot 1 - East Facing photo).

Although the thinning project objectives aim to result in second-growth stand structures with redwoods dominating, the shade-intolerant Douglas-fir will likely remain dominant in the upper canopy until larger gaps are formed (Van Mantgem et al., 2017). The height distribution in relation to the diameter at breast height showed a typical trend as expected, this trend being that Douglas-fir would grow more than redwood and tanoak in diameter range and height with the exception of the three largest redwoods that were preserved (Figure 4). This is understandable given that in past studies Douglas-fir has experienced significant accelerated growth rate after thinning treatments were performed (Plummer et al, 2012).

As a result of reduced basal area from the thinning, tree seedlings were able to sprout in the available open space. It was determined that the more vigorous the thinning treatment, the more regeneration that occurred. In silvicultural practice, thinning dense young stands to increase growth and heterogeneity of understory vegetation is commonly used to increase available resources for plant uptake (Davis, 2009). When allowing for natural recovery rather than active planting management, past studies have found that understory recovery will be more effective and allow for more species diversity (Hanover et al., 2018). Overall, increased overstory variability encourages development of multiple layers of understory vegetation (Ares, 2009).

Even though Douglas-fir was the dominant mature tree species throughout the three plots, there were no observed Douglas-fir seedlings. Douglas-fir is a shade intolerant species, making it likely difficult for new production of seedlings to successfully germinate in comparison to highly shade tolerant tree species (Ares et al., 2009) like redwood, tanoak, and western hemlock. These shade tolerant species are able to grow underneath the canopy cover of the mature trees. There were no observed mature western hemlock trees in close vicinity to the plots, but it can be inferred that their seeds from a higher elevation found their way downslope and became established through wind dispersal. Comparatively, the coast redwood has the characteristic of being able to sprout from stumps approximately two years after a disturbance or harvest (O'Hara et al, 2017). This can account for the high regeneration of redwood seedlings that were observed among the plots (Figure 7).

After analyzing our findings, we discussed possible restoration management practices that can be implemented. For future management uses, the regenerated redwood sprouts can be managed through thinning to create a stand dynamic that would be similar to an old growth forest structure. This would allow for individual redwoods to accelerate their growth, and expand stand growth for timber production (O'Hara et al., 2017). One way to accomplish this is to reduce the amount of mature Douglas-fir trees to shift the dominant species back to redwoods and furthermore create gaps in the canopy that will facilitate in the growth of the redwood sprouts. Additionally, our community partner, Jason Teraoka, discussed with us the future possibility of comparing the amount of ground cover in relation to canopy cover depending on the treatment severity on each plot.

Redwood National Park has a solid foundation that is leading towards the recovery of redwood forests' health. With past and future attempts made, Redwood National Park can determine which practices are effective as a restoration tool. Overall, the use of silvicultural prescriptions as a restoration tool can help rehabilitate these impaired coastal redwood forests. Low thinning in this particular stand showed to be an effective tool for promoting tree growth and ground vegetation diversity. However, each stand is complex and different from one another, therefore prescriptions will vary.

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Appendix I. Photos taken at plot center in the four cardinal directions and directly above to show canopy cover.

Plot 1

North Facing & Canopy Cover

South Facing & Canopy Cover

East Facing & Canopy Cover

West Facing & Canopy Cover

Plot 2

North Facing & Canopy Cover

South Facing & Canopy Cover

East Facing & Canopy Cover

West Facing & Canopy Cover

Plot 3

North Facing & Canopy Cover

South Facing & Canopy Cover

East Facing & Canopy Cover

West Facing & Canopy Cover