



Plant Community Monitoring for Redwood Forest in the San Francisco Bay Area Network

2015 Annual Report

Natural Resource Data Series NPS/SFAN/NRDS—2019/1228



ON THE COVER

Redwood forest plot, Muir Woods National Monument, 2015.

NPS/Eric Wrubel

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Contents

	Page
Figures.....	v
Tables.....	vi
Abstract.....	vii
Acknowledgments.....	vii
Introduction.....	1
Redwood Forest Community Description.....	1
Methods.....	3
General monitoring design and plot establishment	3
Methodologies for measurement of vegetation structure and species composition	6
Plant cover in 1 square meter quadrats.....	6
Woody plant and vine cover along 12 meter transects.....	6
Taxonomic richness in 1 square meter quadrats and 7.32 meter radius circular plots	8
Tree density and basal area.....	8
Tree seedling density.....	9
Fuel load.....	10
Results.....	12
Ground cover and foliar cover metrics.....	12
Plant cover in 1 square meter quadrats.....	12
Woody plant and vine cover along 12 meter transects.....	13
Vegetation composition metrics	15
Forest community metrics	17
Tree density and basal area.....	17
Tree seedling density.....	19
Fuel load	19
Special-status and invasive plants	19

Contents (continued)

	Page
Special status plants.....	20
Invasive plants.....	20
Photo monitoring.....	20
Field Notes	22
Literature Cited	23
Appendix A: All Vascular Plants Observed in Redwood Forest Plots in 2015.....	25

Figures

	Page
Figure 1. Extent of coast redwood forests in PORE and GOGA, and plot locations.....	2
Figure 2. A stand selected for sampling.....	4
Figure 3. Graphical representation of the plot	5
Figure 4. Graphical representation of the 12m transects.....	7
Figure 5. Circular plot and subplot	9
Figure 6. Tree seedling density quadrats.....	10
Figure 7. Fuels transects.....	11
Figure 8. Live plants with 1% or greater cover found in 1m ² quadrats	13
Figure 9. Live woody plants and vines observed on 12m transects.....	15
Figure 10. Photo monitoring points taken from a plot center along the three 15m transects A, B, and C.....	21

Tables

	Page
Table 1. Slope and aspect of the redwood forest plots.....	5
Table 2. Tree life stage categories by size class.....	9
Table 3. Time lag fuel classes of dead and down woody debris.	11
Table 4. Ground and foliar cover measured in the 1m ² quadrats	12
Table 5. Herbaceous plant cover and other metrics evaluated with point intercept in 1m ² quadrats.....	12
Table 6. Live plant taxa with 1% or greater cover found in 1m ² quadrats.....	13
Table 7. Woody plant cover and other metrics evaluated with point intercept on 12m transects.....	14
Table 8. Live woody plants and vines observed along 12m transects	14
Table 9. Number of taxa observed by Life Form, Nativeness, and Special Status.	16
Table 10. Plant taxonomic richness by 1m ² quadrats and 168.3m ² circular plots.....	16
Table 11. Frequency of taxa occurring in more than 15% of the 7.32m radius plots.	16
Table 12. Tree stem density and basal area.....	18
Table 13. Tree seedling density in 3m ² quadrats.....	19
Table 14. Fuel load. Dead and down woody debris (DWD), litter, and duff.....	19
Table 15. Invasive plant taxa frequency in 7.32m radius plots, Cal-IPC ratings, and early detection priority levels.....	20

Abstract

This report summarizes monitoring data collected in redwood forest vegetation in 2015 by the San Francisco Bay Area Inventory and Monitoring Network (SFAN), under its Plant Community Monitoring Protocol (Steers et al. 2016a), which tracks changes in vegetation structure and composition over time in select plant communities. SFAN established and monitored 18 permanent plots in redwood forest vegetation at Golden Gate National Recreation Area and Point Reyes National Seashore in 2015, the first year of protocol implementation in a four-year sampling cycle.

The monitoring plots were each located in a separate stand of redwood forest vegetation, randomly selected from the park vegetation map. Each plot was established at a random point within the stand, and was delimited by a 17.95m radius circle. The plots contain a 7.32m radius subplot, with three 15m transects radiating from the plot center, each with a 1m² quadrat placed equidistant from the plot center. Field observers measured vegetation structure and composition metrics in the plots using several sub-protocols.

We summarize data at the square meter scale for vascular plant cover by taxa, total live and dead vegetation cover, total live and dead herbaceous cover, total native and non-native herbaceous cover, litter, bare ground, total foliar cover, and taxonomic richness. We summarize percent cover data from the 12m transects for woody plant and vine taxa, herbaceous plants, litter, and bare ground. At the 168m² scale we report mean taxonomic richness, frequency of taxa, and number of taxa by life form and nativeness. We estimate tree density, basal area, and tree seedling density, per hectare. We report on occurrences of special-status and invasive plants, provide qualitative field notes, and present an appendix listing all vascular plants observed among all the plots.

Acknowledgments

This work could not have been accomplished without insights and guidance from the lead vegetation managers at San Francisco Area National Parks: Alison Forrestel, Lorraine Parsons, Brent Johnson, and Fernando Villalba. We are also indebted to the San Francisco Area Network Inventory and Monitoring Program's data manager Sarah Wakamiya and the program manager, Daniel George. Finally, we wish to thank our dedicated and brilliant 2015 vegetation ecology interns, Raphaela Floreani Buzbee and Kristofer Daum, who were integral to the field work, data collection, and data quality for this report.

Introduction

This report presents data collected by the San Francisco Bay Area Network of National Parks (SFAN) Inventory and Monitoring Program under its Plant Community Monitoring Protocol (Steers et al. 2016a). The program seeks to track changes over time in structure and species composition in 21 selected plant communities in SFAN parks. One of these communities is redwood forest, which occurs in the coastal park units at Point Reyes National Seashore (PORE) and Golden Gate National Recreation Area (GOGA). 2015 was the first year of long-term monitoring for redwood forest under the Steers et al. (2016a) protocol.

Redwood Forest Community Description

The redwood forest alliance (Sawyer et al. 2009) is a coniferous community dominated by, coast redwood (*Sequoia sempervirens*). Common co-dominant trees include *Pseudotsuga menziesii*, *Umbellularia californica*, and *Notholithocarpus densiflorus* (Sawyer et al. 2009). Understory shrubs may include *Corylus cornuta*, *Symphoricarpos albus*, and *Vaccinium ovatum*. Sword fern (*Polystichum munitum*) can dominate the herbaceous layer. Other associated herbs include *Dryopteris arguta*, *Galium triflorum*, *Oxalis oregana*, *Stachys rigida*, *Trientalis latifolia*, and *Trillium* spp.

Coast redwood forests occur in fog-influenced areas along the California coast from Big Sur to just over the Oregon border. Within the coast redwood range, year-round temperatures are mild, winter precipitation is relatively high, and fog contributes significant summer moisture. The coast redwood is one of the fastest growing conifers in the world. Trees attain a height of up to 120 meters and an age of over 2,000 years. These trees produce high seed counts annually, but seeds have poor dispersal and viability. Coast redwoods are well adapted to fire disturbance, with protective bark and the ability to sprout vigorously after damage to trunks, branches, and roots.

The primary conservation concern for coast redwood forests is severe habitat alteration due to logging. Only five percent of the original old-growth coast redwood forest remains over the historic range. Almost all redwood forest stands in SFAN parks are second-growth, having been logged in the late 19th and early 20th centuries, except for the protected old-growth groves at Muir Woods. Current threats to coast redwood forests in SFAN include potential changes in precipitation and fog regimes due to climate change, especially as the parks are near the southern end of the coast redwood range. Plant pathogens such as Sudden Oak Death (SOD) also pose a threat to redwood forests. Tanbark (*Notholithocarpus densiflorus*), a common co-dominant, is heavily impacted by SOD. Areas of high visitor use, such as Muir Woods have greater exposure to introductions of pathogens and other types of invasive species.

Coast redwood forests occur in GOGA on Bolinas Ridge, at Muir Woods, and at the Phleger Estate in San Mateo County (Figure 1). At PORE, small stands occur on the southeast flank of Inverness Ridge.

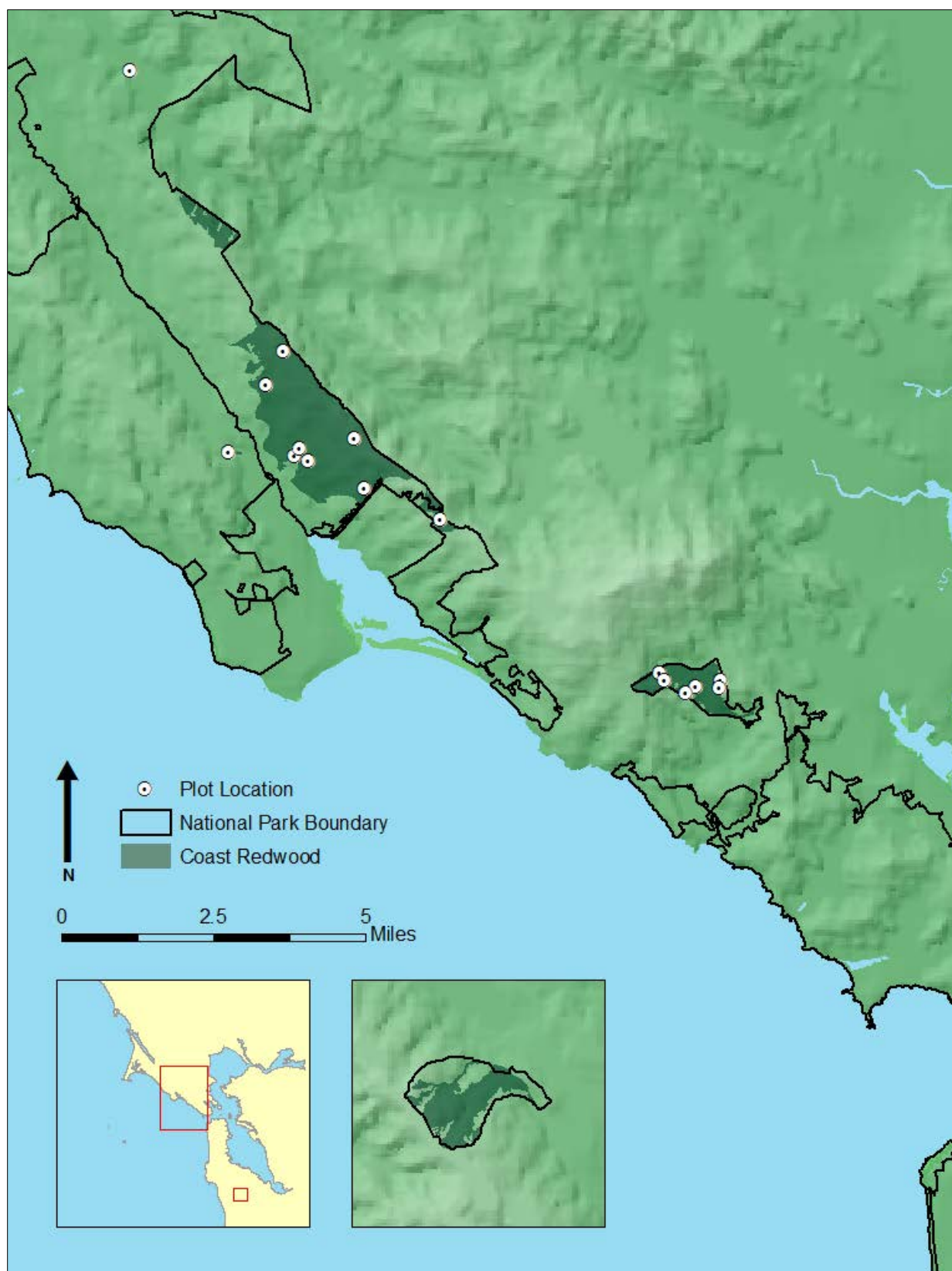


Figure 1. Extent of coast redwood forests in PORE and GOGA, and plot locations.

Methods

In 2015 biologists with the SFAN Inventory and Monitoring Program established 18 permanent monitoring plots in redwood forest at PORE and GOGA to track changes in vegetation structure and community composition over time. The full methodology for site selection and plot establishment is described in the document *Plant Community Monitoring Protocol for the San Francisco Bay Area Network of National Parks, Standard Operating Procedures* (Steers et al. 2016b). Below is a synopsis of the approach for plot establishment and data collection.

General monitoring design and plot establishment

In order to identify redwood forest community locations in SFAN parks, SFAN ecologists selected units mapped to the coast redwood alliance from the Plant Community Classification and Mapping Project for PORE and GOGA (Schirokauer et al. 2003, Steers et al. 2016a, Appendix A and B). We rejected initial attempts to select finer-scale classification units from the *Sequoia sempervirens* - *Pseudotsuga menziesii* - *Umbellularia californica* association after field validation revealed that these units were not reliably mapped to the association level, but were reliably mapped to the coast redwood alliance.

From the Schirokauer et al. vegetation map GIS, SFAN staff randomly selected a set of spatially-distributed polygons (or “stands”) within this fine-scale vegetation type to represent the redwood forest community. SFAN staff filtered out potential sites located on slopes greater than 30 degrees due to safety concerns and to reduce sampling disturbance. A power analysis of pilot data determined the number of stands needed to meet program objectives (Steers et al. 2016b SOP 5). Figure 1 shows the general extent of redwood forest, and the plot locations.

We established one sampling plot within each of 18 selected stands (e.g., Figure 2) randomly using the following procedure: in GIS, we generated the coordinates of ten randomly located candidate points within a 20m interior buffer of the polygon, to accommodate the 17.95m radius of the circular sampling plot. In the field, we navigated to the first randomly identified coordinates, and evaluated the location. We accepted plot locations if they met the following criteria: location represents the target vegetation, plot does not intersect a road or trail, location does not pose immitigable risks to field crews, and location is on a less than 30 degree slope (Steers et al. 2016b SOP 5). If we rejected the first plot location, we then evaluated the next nearest random coordinates sequentially to find an acceptable stand.

Three sample locations were rejected due to unsafe conditions below hazard trees in advanced stages of decay from Sudden Oak Death. Twenty three percent of the sample points were rejected because they were on slopes greater than 30 degrees. This is consistent with the landscape position of coast redwood forests in SFAN, which are typically located in the bottom, and lower slopes of steep-sided drainages.

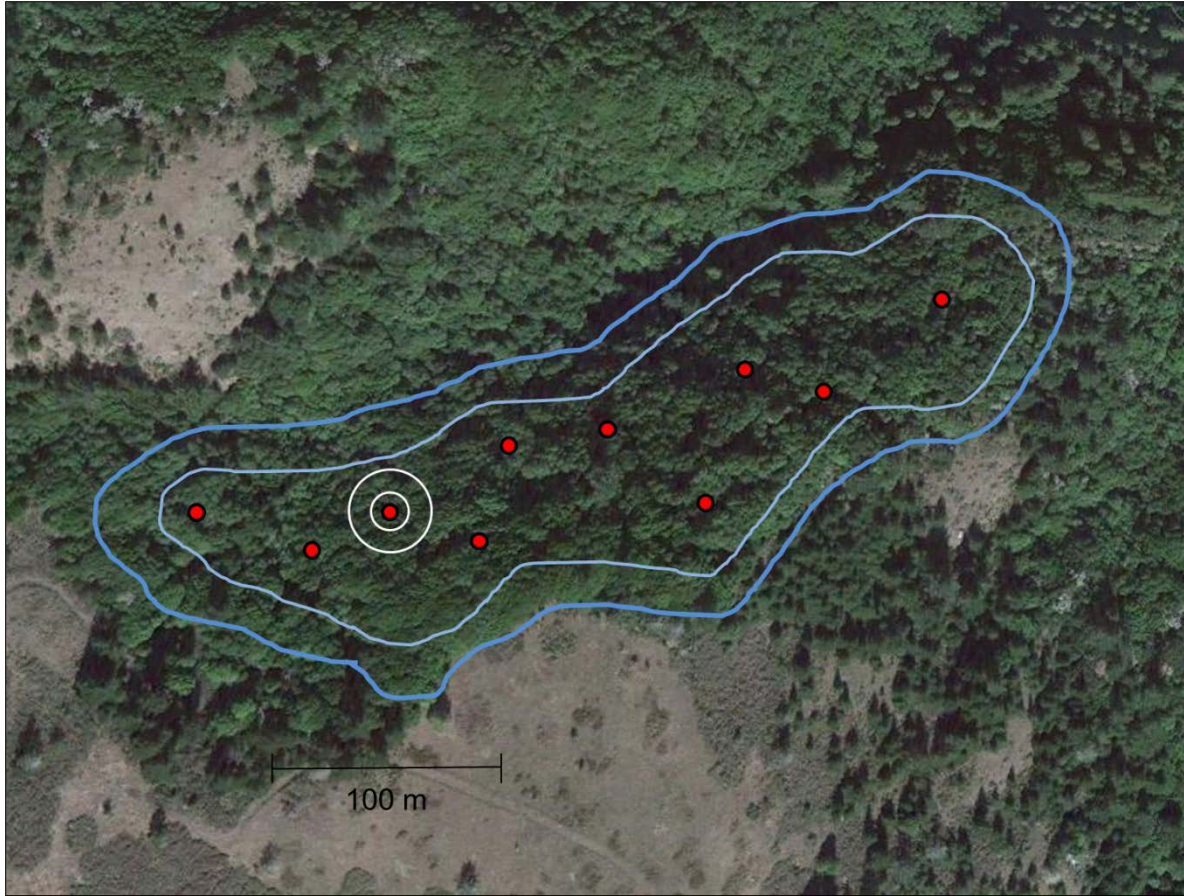


Figure 2. A stand selected for sampling. The stand is outlined in blue, an interior buffer is outlined in light blue, random scouting points are shown in red, and the final sampling plot location is outlined in white.

SFAN staff established 18 monitoring plots in the selected stands in 2015. The plots are located on a variety of exposures (Table 1). The average plot slope was 18 degrees (4 degrees minimum, 31 degrees maximum). Note: one plot slightly exceeded the 30 degree maximum, which may be considered within the margin of error for field measurement by clinometer.

Within stands that met criteria for plot establishment, we created a 17.95m radius circular plot. We monumented each center point with a length of rebar topped with an aluminum cap. We also monumented the ends of each of three 15m transects radiating from the center point at 30°, 150°, and 270° as measured by a compass (Figure 3). Links to photographs of each 15m transect are provided in Appendix B. Within this plot, field observers measured vegetation structure and community composition metrics using several sub-protocols. These are described briefly in section “Methodologies for measurement of vegetation structure and species composition” below, and in more detail in Steers et al. 2016b sections SOP 7 through SOP 12.

Table 1. Slope and aspect of the redwood forest plots.

Plot	Slope (°)	Aspect (°)	Ordinal Direction
1	19	50	NE
2	12	218	SW
3	7	130	SE
4	4	268	W
5	12	220	SW
6	10	71	ENE
7	21	78	E
8	28	76	E
9	24	33	NE
10	24	330	NW
11	17	138	SE
12	24	24	NNE
13	30	308	NW
14	7	228	SW
15	22	176	S
16	13	230	SW
17	21	325	NW
18	31	284	W

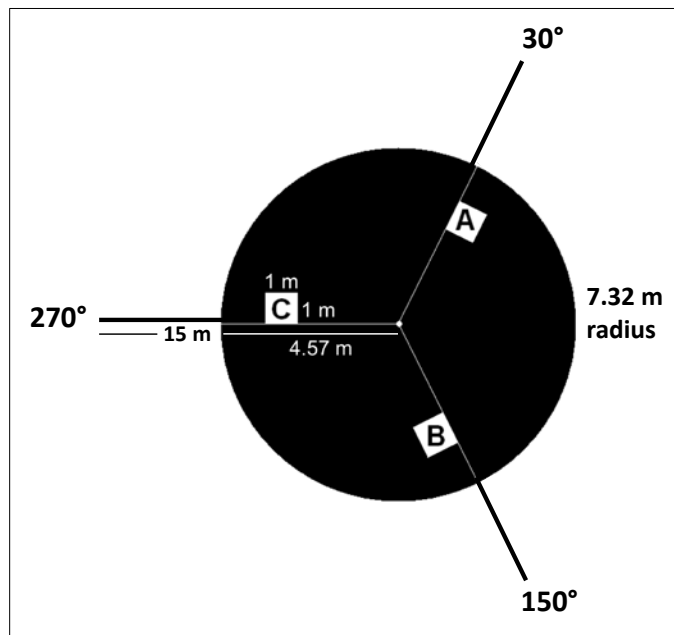


Figure 3. Graphical representation of the plot. Plot components shown include three 15m transects radiating from the plot center, three 1m² quadrats placed along the transects, and the 7.32m radius subplot. Not shown is the 17.95m macroplot.

Methodologies for measurement of vegetation structure and species composition

SFAN staff identified all vascular plants using nomenclature in the Jepson Manual, 2nd edition (Baldwin et al. 2012). Plants were identified to the minimum taxonomic rank (species, subspecies, or varieties), the smallest taxonomic units recognized by the Jepson Manual; however in rare cases we were unable to determine minimum taxonomic rank due to a lack of identifiable characters resulting from unsuitable phenology or disturbances such as herbivory. Prior to data summarization, the SFAN botanist resolved taxonomic ambiguities to the lowest common taxonomic rank possible for each plot, and for the entire dataset, through review of the data and examination of collected plant specimens.

Plant cover in 1 square meter quadrats

Detailed methodology for data collection is found in Steers et al. 2016b SOP 8.

In each of the plots visited in 2015, we measured vascular plant cover in three 1m² quadrats (Figure 3). Although we collected data for all plants less than 3m in height in the quadrats, the primary purpose of this methodology is to evaluate changes in herbaceous plant cover over time. Within each quadrat we evaluated plant presence at 50 regularly dispersed points, by dropping a small-diameter pin flag vertically at each point.

We recorded the name for each plant less than 3m in height that was “hit” by the pin. When we encountered plant material that was dead but still standing as if it were in a live position, we noted the species and recorded it as dead. For woody plants, if we hit both dead and live tissue on the same plant, we recorded both states if the dead tissue was hit above the live tissue, in order to quantify dieback from stem tips. If we hit live tissue above and dead tissue below, we only recorded the live state, because healthy woody plants tend to grow upward and shade out their lower stems, which naturally senesce. At points where no plants were observed, we recorded ground variables at the point, such as “litter” and “bare ground”.

We estimated cover of each plant taxon encountered by first averaging the cover among the three 1m² quadrats measured in each plot, then averaging cover for each taxon among all plots. We calculated cover metrics for “litter” and “bare ground” similarly. We then summarized the plant data broadly, creating metrics for *live vegetation cover*, *dead vegetation cover*, *live herbaceous cover*, *native live herbaceous cover*, and *non-native live herbaceous cover*. We excluded from this analysis any plants with uncertain nativeness (e.g., plants identified to genus only with both native and non-native species within the genus). We then summarized cover data for plants with greater than 1% cover in the quadrats, excluding dead plants from this summary. For all these metrics we created bootstrapped 90% confidence intervals around the estimated mean (Orloff and Bloom 2014). Environmental metrics are presented in Results section “Ground cover and foliar cover metrics” below, while live and dead plant cover data are presented in Results section “Plant cover in 1 square meter quadrats”.

Woody plant and vine cover along 12 meter transects

Detailed methodology for data collection is found in Steers et al. 2016b SOP 10.

We measured woody plant and vine cover on three 12m long transects in each plot (Figure 4), by dropping a small-diameter pin flag vertically at 25cm intervals along the transect. Observers tracked all plants less than 3m in height.

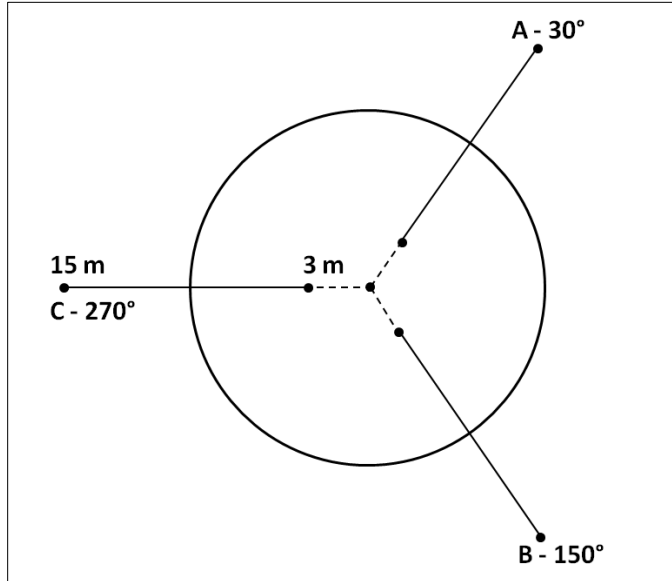


Figure 4. Graphical representation of the 12m transects.

We recorded the name of each woody plant or vine observed in the direct path of the pin. When we encountered plant material that was dead but still standing as if it were in a live position, we noted the species and recorded it as dead. If we hit both live and dead tissue on the same plant, we recorded both live and dead states if the dead tissue was hit above the live tissue, but only recorded the live state if dead tissue was hit below the live tissue, as described above in section “Plant cover in 1 square meter quadrats.” At points where no plants were observed, we recorded alternate variables at the point such as “herbaceous”, “litter” and “bare ground”. Cover of woody vegetation taller than 3m in height observed within the plot was recorded via observation with an upward-pointing device, a GRS densitometer, at 25cm intervals along the transect. We recorded these observations as “tree canopy” hits.

We estimated cover of each plant taxon encountered by first averaging the cover among the three 12m transects measured in each plot, then averaging cover for each plant among all plots. We calculated cover metrics for “litter” and “bare ground” similarly. We then summarized the plant data by *live woody plant or vine*, *dead woody plant or vine*, *live native shrub or subshrub*, *live non-native shrub or subshrub*, *dead shrub or subshrub*, *live vine*, *herbaceous plants*, and *tree canopy*. We excluded from this analysis any plant taxa with uncertain nativeness (e.g., plants identified to genus only with both native and non-native species within the genus). We then summarized cover data for plants with greater than 1% cover along the transects, excluding dead plants from this summary. For all these metrics we created bootstrapped 90% confidence intervals around the estimated mean. Environmental metrics are presented in Results section “Ground cover and foliar cover metrics”

below, while live and dead plant cover data are presented in Results section “Plant cover in 1 square meter quadrats”.

Taxonomic richness in 1 square meter quadrats and 7.32 meter radius circular plots

Detailed methodology for data collection is found in Steers et al. (2016b) SOP 8.

We recorded the presence of all vascular plant taxa rooted in or overhanging each 1m² quadrat at less than 3m in height, then broadened the search area to the circular subplot with radius 7.32m from the plot center point. These observations included both live plants and dead but identifiable plants. We tallied the number of unique (live or dead) plants observed in the three quadrats in each plot, and averaged this number by plot to derive the metric Taxonomic Richness per Square Meter, and tallied the number of plants observed in the 7.32m circular plots to derive the metric taxonomic richness per 168.3m², the areal extent of the plot.

Occasionally, a taxon was only identifiable to the genus level due to unsuitable phenology or disturbance. If we did not identify any other plants in that genus to species in the plot or quadrat, we tallied the genus as one taxon for richness calculations. For example, where observers only recorded *Marah* sp. in the plot or quadrat we tallied it as one taxon. If we identified a plant to genus only and also identified congeneric taxa in the plot or quadrat to a lower taxonomic rank, the genus-only record was not tallied as a unique taxon. For example, where observers recorded *Galium* sp. and also recorded *Galium porrigens* in the plot or quadrat, we tallied these two records as one taxon for richness calculations.

Taxonomic richness metrics are presented in section “Vegetation composition metrics” below.

Tree density and basal area

Detailed methodology for data collection is found in Steers et al. (2016b) SOP 11.

We used the circular 7.32m radius subplot and 17.95m radius macroplot (Figure 5) to measure tree stem density, diameter at breast height (DBH), and sapling density; recording all live and dead taxa categorized as trees by the Jepson Manual (Baldwin et al. 2012).

We categorized tree life stages (i.e., seedling, sapling, tree) by size class as shown in Table 2. Within the 7.32m radius subplot we counted the number of all trees < 20cm DBH and the number of saplings. Within the 17.95m radius macroplot, we counted and recorded DBH for all tree stems ≥ 20 cm DBH. We did not measure tree seedling metrics in the circular plots; rather we collected these data by methods described below in section “Tree seedling density.”

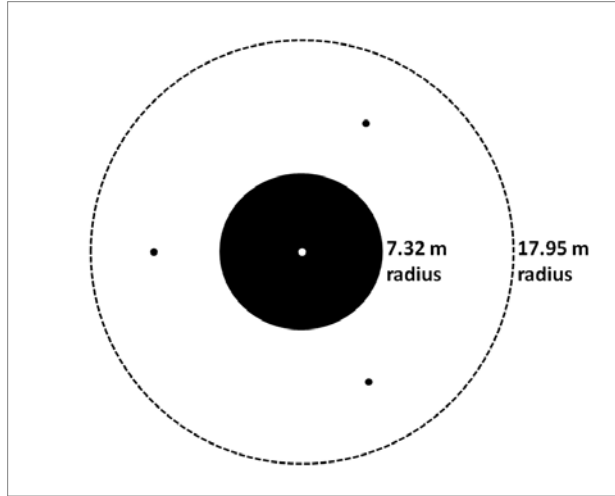


Figure 5. Circular plot and subplot. The 17.95m radius circular plot is marked by the dashed line, and the nested 7.32m radius circular subplot is indicated by the black circle. Also shown are the center point and the 15m ends of the three line transects.

Table 2. Tree life stage categories by size class.

Life stage	Height (m)	DBH (cm)
Tree	≥ 1.37	≥ 5
Sapling	≥ 1.37	< 5
Seedling	< 1.37	N/A

We estimated tree stem density for each tree taxon in each plot by calculating density per hectare for the 7.32m radius subplot (for stems < 20 cm DBH), and for the 17.95m radius macroplot (for stems ≥ 20 cm DBH), then summing these two values. We then we averaged stem density of each plot among all plots. We followed the same procedure to estimate basal area per hectare, using the formula given for basal area in the NPS Fire Monitoring Handbook (NPS 2003). We then summarized mean density and basal area by categories: *live native tree*, *dead native tree*, *live native sapling*, and *dead native sapling, tree*. We repeated this calculation for all live tree taxa, and dead tree taxa. For all these metrics we created bootstrapped 90% confidence intervals around the estimated mean.

Tree density and basal area metrics are presented in section “Tree density and basal area” below.

Tree seedling density

Detailed methodology for data collection is found in Steers et al. 2016b SOP 9.

In each plot, we measured tree seedling density in three 9m² quadrats (Figure 6). Within each quadrat we counted the number of tree seedlings by taxon. The protocol defines seedlings as individuals with stems < 1.37 m tall (Table 2).

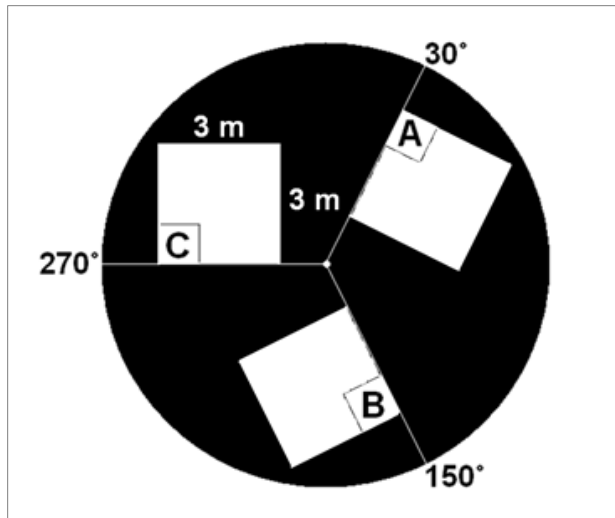


Figure 6. Tree seedling density quadrats. Three 9m² (3m x 3m) quadrats are placed on the transects, overlaying the 1m² quadrats as shown. The 7.32m radius subplot is shown in black. The 17.95m radius macroplot is not shown.

We estimated seedling density of each tree taxon by first averaging among the three 9m² quadrats per plot, then averaging for each tree taxon among all plots. We then created bootstrapped 90% confidence intervals around the estimated mean.

Seedling density metrics are presented in Results section “Tree seedling density” below.

Fuel load

Detailed methodology for data collection is found in Steers et al. 2016b SOP 12. Sampling and analysis follows guidelines from the NPS Fire Monitoring Handbook (NPS 2003) which utilizes Brown’s method (Brown 1974).

We measured dead and down woody debris (DWD), litter, and duff using three 12.5m transects radiating from the plot center (Figure 7). We counted the intersections of DWD particles along the transects categorized by diameter size classes, or time lag classes (Table 3). We recorded observations of fine woody debris (1, 10, and 100 hour time lag classes) on transect A as follows: for observations between 13-15m on the tape we noted 1 hour and 10 hour time lag classes; for observations along the tape between 11-15m we noted 100 hour time lag classes. We recorded observations of coarse woody debris (1,000 hour time lag classes, sound and rotten) on transects A, B, and C between 2.5m and 15m. We recorded litter and duff depth at 2.5m and 8m on transect A.

We calculated fuel loads using formulae from the NPS Fire Monitoring Handbook (NPS 2003), using the default constants for quadratic mean diameter and specific gravity for western forests from the FEAT/FIREMON database (www.frames.gov/ffi). We estimated tons per acre for DWD time lag classes, litter, and duff for each plot, then averaged among all plots, and created bootstrapped 90% confidence intervals around the estimated mean.

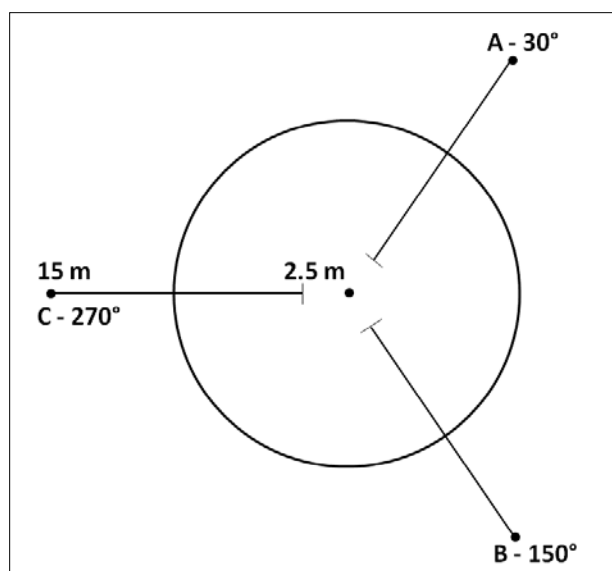


Figure 7. Fuels transects. The 12.5m transects radiating from the plot center. Litter, duff and fine woody debris are sampled on the A transect only, while coarse woody debris is sampled on all three transects from the 2.5m to the 15m marks. Also shown is the 7.32m radius subplot.

Table 3. Time lag fuel classes of dead and down woody debris.

Time Lag Fuel Class	Size Class (cm)	Size Class (in)
1 hour	0-0.62	0-0.25
10 hour	0.63-2.54	0.26-1.00
100 hour	2.55-7.60	1.01-3.00
1000 hour (sound and rotten)	> 7.60	> 3.00

Fuel load metrics are presented in section “Fuel load” below.

Results

Ground cover and foliar cover metrics

Estimated cover of litter was 61.7% in the 1m² quadrats, and 65.2% on the 12m transects (Table 4). Estimated cover of bare ground was 0.6% in the 1m² quadrats, and 0.3% on the 12m transects. The foliar cover observed in the 1m² quadrats (that is, all area covered by at least one layer of vegetation at less than 3m in height) was 37.7%.

Table 4. Ground and foliar cover measured in the 1m² quadrats. Showing the mean percent cover estimate and 90% confidence interval (CI) around the mean.

Cover	1m ² quadrats		12m transects	
	Estimated Cover	90% CI	Estimated Cover	90% CI
Litter	61.7	58.0 - 65.2	65.2	60.6 - 70.1
Bare Ground	0.6	0.1 - 1.0	0.3	0 - 0.5
Total Foliar Cover	37.7	–	–	–

Plant cover in 1 square meter quadrats

The estimated absolute cover of all live vascular plant taxa calculated across all 1m² quadrats was 33.2% (Table 5). Absolute cover of all taxa may include overlapping canopies; therefore it may exceed total foliar cover, which is presented above in Table 4. The absolute cover of dead vascular plants was 5.0%.

The estimated absolute cover of live herbaceous plants was 8.8%, with 100% of that represented by native species.

Table 5. Herbaceous plant cover and other metrics evaluated with point intercept in 1m² quadrats. Showing the mean percent cover estimate and 90% confidence interval (CI) around the mean.

Cover	Estimated Cover	90% CI
Total Live Vegetation	33.2	28.2 - 38.1
Total Dead Vegetation	5.0	3.1 - 6.8
Total Live Herbaceous	8.8	4.9 - 12.3
Native Live Herbaceous	8.8	4.9 - 12.3
Non-native Live Herbaceous	–	–

Plants with 1% or greater cover within the 1m² quadrats are shown in Table 6 and Figure 8 below. All plants with 1% or greater cover in these plots are native (Jepson Herbarium 2017). Other plants observed in the quadrats exhibited less than 1% cover. These are included in the complete 2015 species list for redwood forest in Appendix A.

Table 6. Live plant taxa with 1% or greater cover found in 1m² quadrats. Showing the mean percent cover estimate and 90% confidence interval (CI) around the mean.

Taxon	Estimated Cover	90% CI
<i>Sequoia sempervirens</i>	10.0	6.9 - 13.0
<i>Polystichum munitum</i>	6.8	2.8 - 10.4
<i>Vaccinium ovatum</i>	6.0	2.7 - 9.1
<i>Frangula californica</i> subsp. <i>californica</i>	3.0	0.7 - 5.2
<i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	1.8	0.5 - 3.0
<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	1.1	0.0 - 2.1

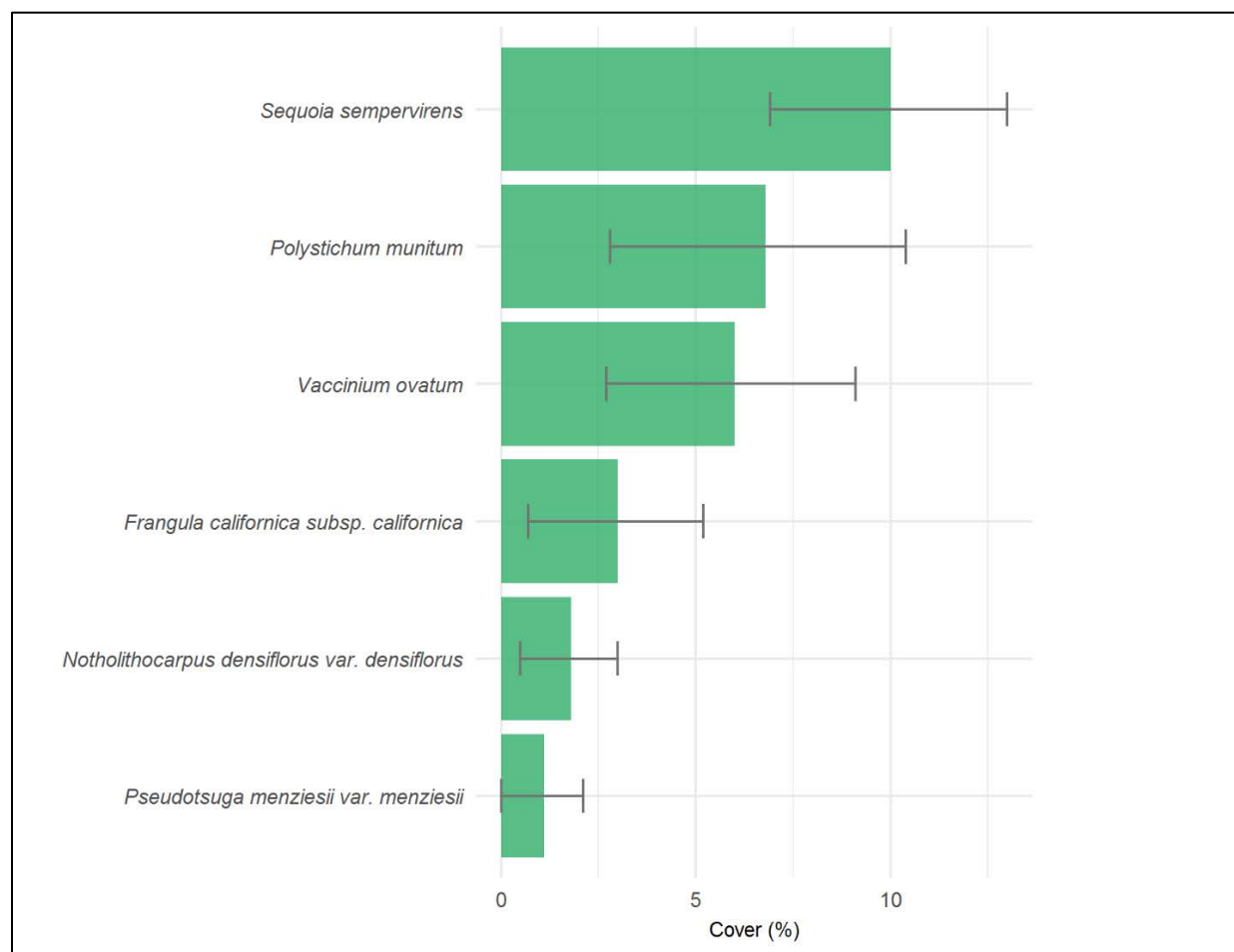


Figure 8. Live plants with 1% or greater cover found in 1m² quadrats. Error bars show 90% confidence intervals around the estimated means.

Woody plant and vine cover along 12 meter transects

Estimated cover of live woody plant or vine taxa calculated across all plots was 24.0% (Table 7). Estimated cover of dead woody plants or vines was 2.4%. Live native tree, shrub or subshrub species comprised 8.7% cover and dead tree, shrub or subshrub cover comprised 0.5% cover. No live non-

native shrubs or subshrubs were observed in 2015. Live vines comprised negligible cover (0.9%). Other variables observed on the 12m transects include herbaceous plants (8.6% cover) and tree canopy (85.1% cover).

Table 7. Woody plant cover and other metrics evaluated with point intercept on 12m transects. Showing the mean percent cover estimate and 90% confidence interval (CI) around the mean.

Life Form	Estimated Cover	90% CI
Live Woody Plant or Vine	24.0	20.4 - 27.6
Dead Woody Plant or Vine	2.4	1.7 - 3.1
Live Native Shrub or Subshrub	8.7	6.2 - 11.2
Live Non-native Shrub or Subshrub	–	–
Dead Shrub or Subshrub	0.5	0.2 - 0.7
Live Vine	0.9	0 - 1.9
Herbaceous	8.6	5.9 - 11.1
Tree Canopy	85.1	82.1 - 88.2

Woody species and vines “hit” along transects are shown in Table 8 and Figure 9.

Table 8. Live woody plants and vines observed along 12m transects. Showing the mean percent cover estimate and 90% confidence interval (CI) around the mean.

Taxon	Estimated Cover	90% CI
<i>Sequoia sempervirens</i>	76.5	71.3 - 81.8
<i>Umbellularia californica</i>	15.9	9.9 - 21.5
<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	8.1	3.9 - 12
<i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	6.1	2.7 - 9.2
<i>Vaccinium ovatum</i>	3.8	1.7 - 5.7
<i>Frangula californica</i> subsp. <i>californica</i>	2.2	0.4 - 3.9
<i>Berberis nervosa</i>	1.4	0.0 - 2.8
<i>Corylus cornuta</i> subsp. <i>californica</i>	1.2	0.2 - 2.2
<i>Notholithocarpus densiflorus</i>	1.2	0 - 2.4
<i>Aristolochia californica</i>	0.8	0 - 1.7
<i>Rubus ursinus</i>	0.4	0 - 0.8
<i>Arbutus menziesii</i>	0.2	0 - 0.3
<i>Hedera helix</i>	0.1	0 - 0.2
<i>Quercus wislizeni</i>	0.1	0 - 0.2
<i>Symphoricarpos albus</i> var. <i>laevigatus</i>	0.1	0 - 0.2
<i>Toxicodendron diversilobum</i>	0.1	0 - 0.2
<i>Mimulus aurantiacus</i> var. <i>aurantiacus</i>	negligible	0 - 0.1
<i>Sambucus racemosa</i> var. <i>racemosa</i>	negligible	0 - 0.1

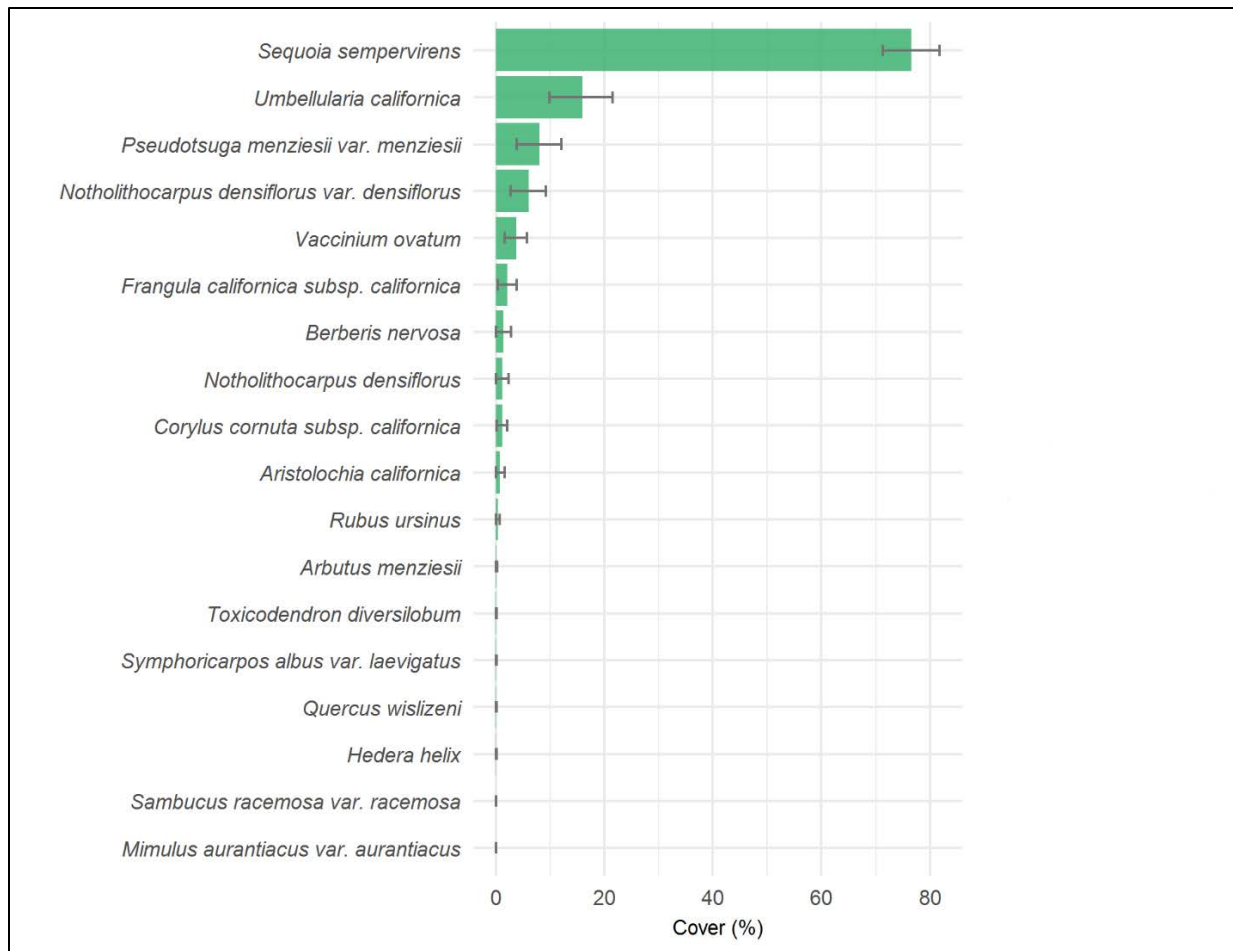


Figure 9. Live woody plants and vines observed on 12m transects. Error bars show 90% confidence intervals around the estimated means.

Vegetation composition metrics

SFAN staff observed 63 unique vascular plant taxa in the circular 6plots, which included 7 tree taxa, 14 shrub and subshrub taxa, 4 vine taxa, and 38 herbaceous taxa (Table 9). Of all taxa observed, 90% were native to California, 6% were non-native herbaceous plants, and 1% were non-native shrubs or vines. Life form and nativeness follow Baldwin et al. (2012). See Appendix A for a list of all vascular plant taxa observed.

The average number of taxa in the 1m² quadrats was 5.6, and the average number of taxa observed in the 7.32m radius (168.3m²) subplots was 14.5 (Table 10).

Of the 63 total taxa observed in the plots, 28 taxa occurred with greater than 15% frequency in the 7.32m² (168.3m²) subplots (Table 11). Of these taxa, 4 were trees, 8 were shrubs or subshrubs, 2 were vines, and 14 were herbaceous plants.

Table 9. Number of taxa observed by Life Form, Nativeness, and Special Status.

Life Form	Nativeness	Number of Species	Percentage of All Species Observed
Tree	Native	7	11%
	Non-native	0	–
Shrub and Subshrub	Native	13	21%
	Non-native	1	1%
Vine	Native	3	5%
	Non-native	1	1%
Herbaceous	Native	34	54%
	Non-native	4	6%
Total	–	63	–

Table 10. Plant taxonomic richness by 1m² quadrats and 168.3m² circular plots. Showing the mean percent cover estimate and 90% confidence interval (CI) around the mean.

Area	n	Mean taxonomic richness	90% CI
Taxonomic richness by 1m ² quadrat	54	5.6	5.1 - 6.1
Taxonomic richness by 168.3m ² circular subplot	18	14.5	12.6 - 16.3

Table 11. Frequency of taxa occurring in more than 15% of the 7.32m radius plots.

Stratum	Taxon Name	Number of Plots	Frequency (%)	Nativeness
Tree	<i>Sequoia sempervirens</i>	18	100	Native
	<i>Umbellularia californica</i>	14	78	Native
	<i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	12	67	Native
	<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	6	33	Native
Woody Plant or Vine	<i>Hedera helix</i>	6	33	Naturalized
	<i>Aristolochia californica</i>	4	22	Native
Shrub or Subshrub	<i>Vaccinium ovatum</i>	12	67	Native
	<i>Symphoricarpos albus</i> var. <i>laevigatus</i>	9	50	Native
	<i>Rubus ursinus</i>	8	44	Native
	<i>Frangula californica</i> subsp. <i>californica</i>	7	39	Native
	<i>Toxicodendron diversilobum</i>	7	39	Native
	<i>Corylus cornuta</i> subsp. <i>californica</i>	5	28	Native
	<i>Lonicera hispidula</i>	3	17	Native
	<i>Rosa gymnocarpa</i> var. <i>gymnocarpa</i>	3	17	Native

Table 11 (continued). Frequency of taxa occurring in more than 15% of the 7.32m radius plots.

Stratum	Taxon Name	Number of Plots	Frequency (%)	Nativeness
Herbaceous	<i>Polystichum munitum</i>	15	83	Native
	<i>Galium triflorum</i>	13	72	Native
	<i>Dryopteris arguta</i>	12	67	Native
	<i>Trillium ovatum</i> subsp. <i>ovatum</i>	11	61	Native
	<i>Stachys rigida</i> var. <i>quercetorum</i>	10	56	Native
	<i>Trientalis latifolia</i>	6	33	Native
	<i>Elymus californicus</i>	5	28	Native
	<i>Oxalis oregana</i>	5	28	Native
	<i>Pteridium aquilinum</i> var. <i>pubescens</i>	5	28	Native
	<i>Prosartes</i> sp.	4	22	Native
	<i>Carex globosa</i>	3	17	Native
	<i>Iris douglasiana</i>	3	17	Native
	<i>Polygala californica</i>	3	17	Native
	<i>Prosartes hookeri</i>	3	17	Native

Forest community metrics

Tree density and basal area

The estimated mean stem density in this community is 617.2 stems/ha of live native saplings and 773.1 stems/ha of live native trees (Table 12). Estimates for dead saplings and dead native trees are 204.6 stems/ha and 183.6 stems/ha, respectively. The stem density estimate for live trees >100cm diameter at breast height (DBH) is 35.7 stems/ha; the estimate for dead trees >100cm DBH is 1.65 stems/ha.

Mean basal area of live native trees was 133.6m²/ha, and mean basal area of dead native trees was 8.4m²/ha. Coast redwood (*Sequoia sempervirens*) had the highest stem density and basal area (1,067.0 stems/ha including both mature trees and saplings, 118.4 m²/ha), followed by California bay (*Umbellularia californica*), and tanoak (*Lithocarpus densiflorus* var. *densiflorus*).

All trees observed in this community are identified as native.

Table 12. Tree stem density and basal area. Showing mean stems per hectare, and mean basal area per hectare, and 90% confidence intervals (CI) around the means.

Life form	Taxon	Density (stems/ha)	90% CI	Basal area (m ² /ha)	90% CI
Live Native Tree (all)	–	773.1	621.4 - 919.3	133.6	119.6 - 147.4
Live Native Tree >100cm DBH	–	35.7	27.4 - 43.9	–	–
Live Native Sapling	–	617.2	277.2 - 920.8	–	–
Dead Native Tree (all)	–	183.6	99.0 - 261.2	8.4	5.4 - 11.1
Dead Native Tree >100cm DBH	–	1.65	0 - 3.29	–	–
Dead Sapling	–	204.6	115.5 - 290.4	–	–
Tree species (mature and sapling)	Live <i>Sequoia sempervirens</i>	1,067.0	616.0 - 1,470.7	118.4	102.5 - 134.0
	Dead <i>Sequoia sempervirens</i>	335.5	209.0 - 458.1	5.6	3.2 - 7.7
	Live <i>Umbellularia californica</i>	182.0	83.5 - 270.5	4.0	2.7 - 5.2
	Dead <i>Umbellularia californica</i>	5.0	0 - 9.9	0.1	0 - 0.3
	Live <i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	94.6	52.8 - 134.7	1.1	0.2 - 1.9
	Dead <i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	16.5	7.7 - 24.7	1.0	0.3 - 1.6
	Live <i>Arbutus menziesii</i>	20.3	0 - 40.7	0.6	0 - 1.3
	Dead <i>Arbutus menziesii</i>	26.9	0 - 53.9	0.5	0 - 0.9
	Live <i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	26.4	7.1 - 43.4	9.5	2.9 - 15.4
	Dead <i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	4.4	0.6 - 8.3	1.3	0 - 2.5

Tree seedling density

Mean density of all tree seedlings in the 3m² subplots was 8,827 stems/ha (Table 13). Coast redwood had the highest mean seedling density (4,815 seedlings/ha), followed by tanoak, and Douglas fir (*Pseudotsuga menziesii* var. *menziesii*).

Table 13. Tree seedling density in 3m² quadrats. Showing mean seedlings per hectare and 90% confidence intervals (CI) around the means.

Taxon	Density (seedlings/ha)	90% CI
<i>Sequoia sempervirens</i>	4,815	1,728 - 7,592
<i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	3,209	988 - 5,185
<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	432	123 - 740
<i>Umbellularia californica</i>	370	185 - 555

Fuel load

Total fuel load of dead and down woody debris (DWD), litter, and duff was 68.5 tons per acre (Table 14). Total DWD was 34.1 tons per acre, or 49.8% of the total fuel load. Total litter and duff was 34.4 tons per acre, or 50.2% of the total fuel load.

Table 14. Fuel load. Dead and down woody debris (DWD), litter, and duff. Showing mean tons per acre and 90% confidence intervals (CI) around the means.

Time Lag Fuel Class	Tons per acre	90% CI
1 hour	3.3	2.7 - 3.8
10 hour	3.3	2.6 - 4
100 hour	3.6	2.4 - 4.9
1000 hour sound	19.9	9.8 - 29.2
1000 hour rotten	4.0	2.2 - 5.7
Litter	13.9	7 - 20.4
Duff	20.5	9.7 - 30.6

Special-status and invasive plants

Special status plants are defined here as taxa that are federally or state listed as rare, threatened or endangered; or candidates for federal or state listing; or included in the California Native Plant Society Inventory of Rare, Threatened, and Endangered Plants (CNPS 2017).

Invasive plants are defined here as taxa that are listed in the California Invasive Plant Council Inventory (Cal-IPC 2017); or listed by the SFAN Invasive Plants Early Detection Program (SFAN 2017). Invasive plants are taxa that are not native to an environment, and once introduced they quickly reproduce and spread, causing harm to the environment, economy, or human health.

Cal-IPC ranks invasive species from high to low by the statewide severity of their ecological impacts, spread rate, and distribution, using the ratings High, Moderate, and Limited. The SFAN early detection program ranks invasive plant species by their risk of invasiveness and distribution in SFAN parks. High priority species are present in isolated locations and pose a high risk of invasiveness; medium priority species are more widespread, and pose a moderate to high risk of invasiveness, or are under surveillance; and low priority species are widespread and abundant, with variable ecological impacts.

Special status plants

One special-status plant, California bottle-brush grass (*Elymus californicus*), was present in five plots (28% frequency). This species is a CNPS Rank 4.3 taxon, meaning it is a plant of limited distribution in California, and it is currently not seriously threatened. It is endemic to the San Francisco Bay region, primarily occurring in forests and woodlands of the coastal counties.

Invasive plants

Four invasive plant species were found within the plots (Table 15). Two species had a Cal-IPC rating of High, one had a Cal-IPC rating of Moderate, and one had a Cal-IPC rating of Limited. Three of these species were also on priority lists for the SFAN Invasive Plants Early Detection Program at GOGA and PORE. One was a medium priority for early detection, and two were low priority.

Table 15. Invasive plant taxa frequency in 7.32m radius plots, Cal-IPC ratings, and early detection priority levels.

Taxon	Cal-IPC rating	SFAN Early Detection Priority	Frequency (%)
<i>Ehrharta erecta</i>	Moderate	Low	5
<i>Genista monspessulana</i>	High	Low	11
<i>Hedera helix</i>	High	Medium	33
<i>Myosotis latifolia</i>	Limited	–	11

Photo monitoring

During each monitoring event, we took photo points at eye-level from plot center along the three 15m transects (A, B, and C). A photographic scale pole marked in 0.5m increments was placed at the 7.32m mark along each transect. High resolution images of all plot photos are stored in NPGallery, and may be viewed at the link below.

[NPGallery: 2015 Redwood Forest Plot Photos](#)

Figure 10 shows an example of three photo monitoring points taken along transects A, B, and C in a redwood forest sample plot.

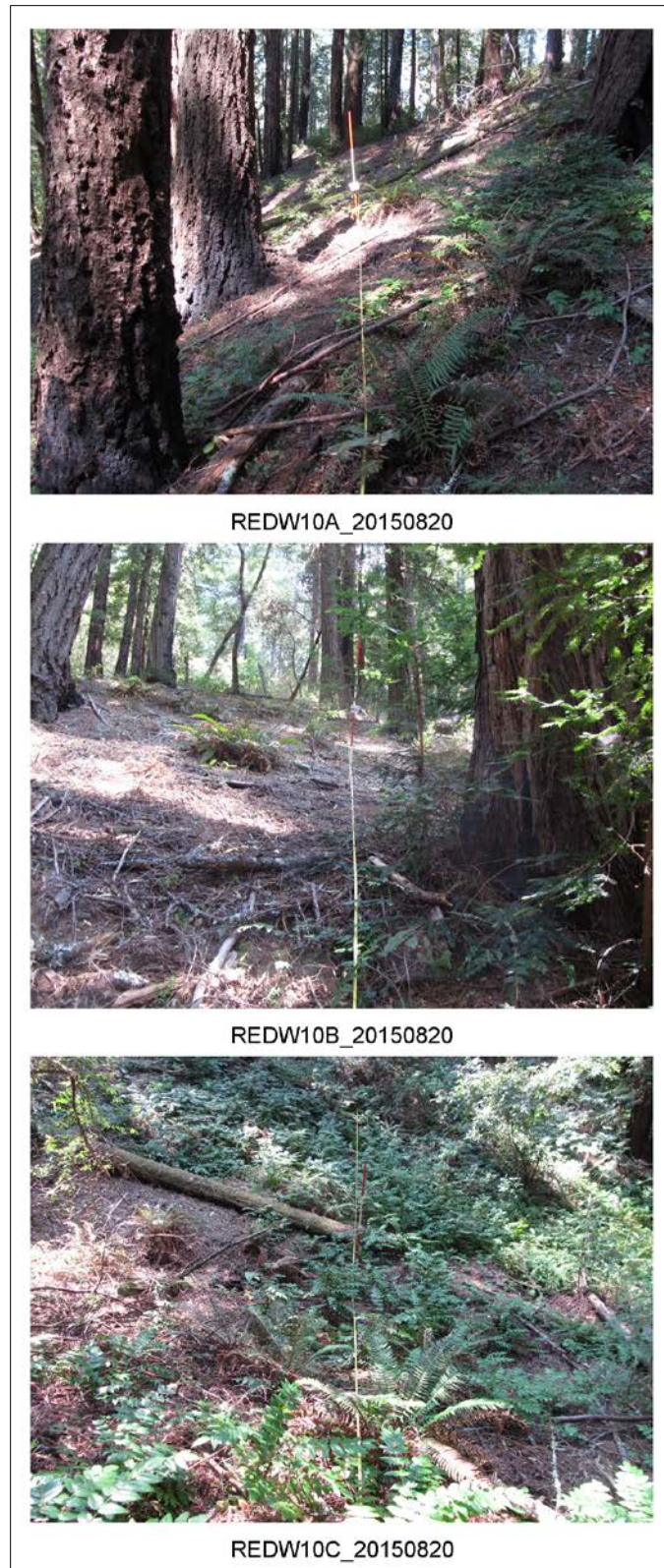


Figure 10. Photo monitoring points taken from a plot center along the three 15m transects A, B, and C. The photo labels indicate the community type (REDW), plot number (10), transect (A, B, C), and date.

Field Notes

Coast redwood forests of the San Francisco Bay Area national parks, and elsewhere, exhibit great variation in structure depending on their land use history. In Muir Woods National Monument, where the forests were not historically logged by clearcutting, “old-growth” stands are dominated by large, old redwood trees, with a sub-canopy composed of multiple species of different age classes, and an open understory with large downed woody debris. In contrast, “second-growth” stands on Bolinas Ridge that have been logged once or twice over the past two centuries contain few very old trees. These stands tend to have higher stem densities of even-aged trees, a less complex canopy, and less large woody debris. Most redwood forest stands sampled at Point Reyes National Seashore and Golden Gate National Recreation Area contain fire-scarred trees. The frequency of fire scars on second-growth trees indicates that forest fires have occurred in many locations since the late 1800s, when logging peaked in the area. None of the stands we visited exhibited signs of recent fire.

We observed high numbers of dead or dying tanoaks impacted by Sudden Oak Death (SOD) disease at numerous locations. Tanoak is an important component of coast redwood forests and is highly susceptible to SOD. Live tanoak saplings remain relatively common, but a majority of large old trees are dead and fallen. This is reflected in the low basal area for both live and dead tanoaks (Table 12). Tanoak die-off appeared especially severe on the Bolinas Ridge, and several sample point locations were rejected there because of safety concerns due to the presence of standing dead trees.

Invasive plant taxa were not present at high levels of cover and were generally infrequent in the redwood forest plots. English ivy (*Hedera helix*) seedlings were moderately frequent, found in 6 of the 18 plots (33%), but large plants were rarely observed.

We identified all vascular plants to the minimum taxonomic rank possible. In two cases we were only able to identify a taxon to genus. A grass identifiable to genus *Melica* could not be resolved to species. This taxon was either *M. subulata* or *M. geyeri*, based on the presence of large corms, closed leaf sheath, and geographic location. It was present in two plots, and was not identifiable to species due a lack of flowers or fruits. In four plots, the genus *Prosartes* was not resolved to species due to a misidentification error. This taxon was either *P. hookeri* or *P. smithii* based on geographic location. *Prosartes hookeri* was correctly identified in three plots, and *P. smithii* was correctly identified in one plot.

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Appendix A: All Vascular Plants Observed in Redwood Forest Plots in 2015

Table A-1. All vascular plants observed in redwood forest plots in 2015.

Life Form	Species	Nativeness*	Status*
Trees	<i>Arbutus menziesii</i>	Native	–
	<i>Notholithocarpus densiflorus</i> var. <i>densiflorus</i>	Native	–
	<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	Native	–
	<i>Quercus wislizeni</i>	Native	–
	<i>Sequoia sempervirens</i>	Native	–
	<i>Torreya californica</i>	Native	–
	<i>Umbellularia californica</i>	Native	–
Shrubs and Subshrubs	<i>Berberis nervosa</i>	Native	–
	<i>Clinopodium douglasii</i>	Native	–
	<i>Corylus cornuta</i> subsp. <i>californica</i>	Native	–
	<i>Frangula californica</i> subsp. <i>californica</i>	Native	–
	<i>Galium californicum</i> subsp. <i>californicum</i>	Native	–
	<i>Genista monspessulana</i>	Naturalized	Weed listed by Cal-IPC
	<i>Lonicera hispidula</i>	Native	–
	<i>Rosa gymnocarpa</i> var. <i>gymnocarpa</i>	Native	–
	<i>Rubus ursinus</i>	Native	–
	<i>Sambucus racemosa</i> var. <i>racemosa</i>	Native	–
	<i>Symphoricarpos albus</i> var. <i>laevigatus</i>	Native	–
	<i>Toxicodendron diversilobum</i>	Native	–
	<i>Vaccinium ovatum</i>	Native	–
	<i>Whipplea modesta</i>	Native	–
Vines	<i>Aristolochia californica</i>	Native	–
	<i>Calystegia purpurata</i> subsp. <i>purpurata</i>	Native	–
	<i>Hedera helix</i>	Naturalized	Weed listed by Cal-IPC
	<i>Lathyrus vestitus</i> var. <i>vestitus</i>	Native	–
Herbaceous Plants	<i>Adenocaulon bicolor</i>	Native	–
	<i>Adiantum aleuticum</i>	Native	–
	<i>Aralia californica</i>	Native	–
	<i>Bromus laevipes</i>	Native	–
	<i>Bromus vulgaris</i>	Naturalized	–
	<i>Carex globosa</i>	Native	–
	<i>Circaea alpina</i> subsp. <i>pacifica</i>	Native	–

*Nativeness and Status from Jepson Herbarium eflora <http://ucjeps.berkeley.edu/eflora/>

Table A-1 (continued). All vascular plants observed in redwood forest plots in 2015.

Life Form	Species	Nativeness*	Status*
Herbaceous Plants (continued)	<i>Clintonia andrewsiana</i>	Native	–
	<i>Cyperus eragrostis</i>	Native	–
	<i>Cystopteris fragilis</i>	Native	–
	<i>Dichondra donnelliana</i>	Native	–
	<i>Dryopteris arguta</i>	Native	–
	<i>Ehrharta erecta</i>	Naturalized	Weed listed by Cal-IPC
	<i>Elymus californicus</i>	Native	CNPS Rare or Endangered List
	<i>Festuca occidentalis</i>	Native	–
	<i>Fragaria vesca</i>	Native	–
	<i>Galium triflorum</i>	Native	–
	<i>Iris douglasiana</i>	Native	–
	<i>Juncus hesperius</i>	Native	–
	<i>Maianthemum stellatum</i>	Native	–
	<i>Melica</i>	Native	–
	<i>Myosotis latifolia</i>	Naturalized	Weed listed by Cal-IPC
	<i>Osmorhiza berteroi</i>	Native	–
	<i>Oxalis oregana</i>	Native	–
	<i>Polygala californica</i>	Native	–
	<i>Polystichum munitum</i>	Native	–
	<i>Prosartes hookeri</i>	Native	–
	<i>Prosartes smithii</i>	Native	–
	<i>Pteridium aquilinum</i> var. <i>pubescens</i>	Native	–
	<i>Scrophularia californica</i>	Native	–
	<i>Senecio minimus</i>	Naturalized	–
	<i>Stachys rigida</i> var. <i>quercetorum</i>	Native	–
	<i>Trientalis latifolia</i>	Native	–
	<i>Trillium ovatum</i> subsp. <i>ovatum</i>	Native	–
	<i>Urtica dioica</i> subsp. <i>gracilis</i>	Native	–
	<i>Viola glabella</i>	Native	–
	<i>Viola sempervirens</i>	Native	–
	<i>Woodwardia fimbriata</i>	Native	–

*Nativeness and Status from Jepson Herbarium eflora <http://ucjeps.berkeley.edu/eflora/>

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 612/154788, 641/154788, June 2019

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