DENDROANTHROPOLOGICAL APPLICATIONS IN ADAPTIVE MANAGEMENT: A MULTI-METHODOLOGICAL APPROACH FOR INTERPRETING CULTURAL LANDSCAPE CHANGE AT MVS-YEE-SE'-NE

By

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A Thesis Presented to

The Faculty of Humboldt State University

In Partial Fulfillment of the Requirements for the Degree

Master of Arts in Applied Anthropology

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May 2020

ABSTRACT

DENDROANTHROPOLOGICAL APPLICATIONS IN ADAPTIVE MANAGEMENT: A MULTI-METHODOLOGICAL APPROACH FOR INTERPRETING CULTURAL LANDSCAPE CHANGE AT MVS-YEE-SE'-NE

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This thesis combined GIS analysis, archival research, and dendrochronological methods to provide a means for interpreting how the Mvs-yee-se'-ne cultural landscape has changed since the period of European contact circa 1850. By employing dendrochronological methods, a unique stand of Oregon white oak (*Quercus garryana*) was found to be present at Mvs-yee-se'-ne by at least 1809. Since 1850, factors such as American colonization, homesteading, mining, fire suppression, and logging have had an effect on cultural landscapes such as Mvs-yee-se'-ne regionally, but this research localized such effects in a site-specific context. Aerial imagery analysis conducted for this thesis documented extractive activities, such as logging, occurring on the parcel. The effect being that in some areas of Mvs-yee-se'-ne, nearly 50% of open grassland spaces were lost to encroaching conifers. This type of environmental reconstruction can assist land managers and Tribal governments in visualizing ecological restoration goals they hope to accomplish at Mvs-yee-se'-ne and provide an informative baseline from which a site management plan for Mvs-yee-se'-ne can be developed in the near future.

ACKNOWLEDGEMENTS

This research would not have been possible without those that came before; those who manicured the landscape and tended the oaks that survive today, to be utilized, protected, and revered. Special thanks are given to the Tolowa Dee-Ni' Nation and Elk Valley Rancheria for allowing me to conduct research in their homeland, specifically tribal members Suntayea Steinruck, Kevin Mealeu, Cynthia Ford, Kagat McQuillen, Jaytuck Steinruck, Amanda O' Connell, and Pyuwa Bommelyn. Their willingness to collaborate and guide me in this process has made this project all the more meaningful. The Six Rivers National Forest was also extremely supportive in allowing me the time and funding to complete this research; Dr. Jennifer Dyer was primarily responsible for keeping me focused on school and has been one of my greatest advocates. Thanks are also given to those individuals that helped me gather my field data, and my appreciation goes out to the patient professors and staff of the Anthropology and Geography Departments at HSU, particularly Kelly Muth. Lastly but most importantly, thank you to my children and my husband who remind me every day of the things I am most grateful for: love, life, and the opportunities to grow.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

For over 30 years, the U. S. Forest Service has administered a 40-acre parcel on the Middle Fork Smith River in Del Norte County referred to collectively as “Mus-Lye[1]”, “Mus-Yeh-Sait-Neh[2]”, “Mvs-yee-se’-ne[3]”, or Pappas Flat. Through consultation and collaborative efforts with the Tolowa Dee-Ni’ Nation (formerly Smith River Rancheria), Elk Valley Rancheria, and Tolowa Nation, Mvs-yee-se’-ne was enumerated on the National Register of Historic Places (NRHP) in 1993 as one of the first cultural landscapes to be officially associated with events that have made a significant contribution to understanding the broad patterns of American history (Keter 1993).

One of its defining features is a 15-acre Oregon white oak (*Quercus garryana*) woodland (Figure 1). The woodland is an ecological anomaly: Oregon white oaks in California are more prevalent today in Humboldt and Mendocino Counties, while Del Norte County possesses far less acreage of oak woodland. Gaman and Firman estimated that Oregon white oak was the dominant canopy cover for only 355 acres in Del Norte County as compared to over 100,000 acres in Humboldt County and more than 283,000 acres in Mendocino County (Gaman and Firman 2006:614). Acreage for Oregon white oak increased again north of the study area covering an estimated 400,000 acres throughout western Oregon and Washington (Fowells 1965).

[1]Tolowa Translation: “beneficial underneath” (Bommelyn in Tushingham 2013).
[2]Tolowa translation: “down below Mus-yeh” (Bommelyn in Keter 1993).
[3]Current phonemic spelling (http://www.weeyadvn.com/tolowa-dictionary/ , accessed April 7, 2020).

Figure 1. Oak woodland at Mvs-yee-se'-ne (2017). Courtesy of Sheila Balent, Fuels Planner, Smith River National Recreation Area.

While Gaman and Firman’s estimates were derived using Geographic Information Systems (GIS) and subject to field correction, the sheer lack of Oregon white oak in Del Norte County makes Mvs-yee-se’-ne a significant ecological landscape with important environmental and cultural implications for ongoing conservation efforts. This 15 acres was differentiated from the rest of the adjacent coniferous canopy, which was comprised mostly of Douglas-fir (*Pseudotsuga menziesii*). The parcel also incorporated an open

Jeffrey pine grassland (*Pinus jeffreyi*) on about 4 acres where noticeable conifer encroachment was present (Figure 2).

Figure 2. Sample tree JP3B, Jeffrey pine grassland at Mvs-yee-se'-ne. Dense incense cedar and Douglas-fir in background. Photograph by Brandy Clark (2019).

Mvs-yee-se’-ne is one of many locations in Northwestern California suffering from the impacts of conifer encroachment. The encroachment of conifers into open woodland landscapes is a well-studied local phenomenon (e.g. Cocking et al. 2015; Engber et al. 2011; Schriver and Sherriff 2015; Schriver et al. 2018), and is generally thought to pose the most extensive and urgent risk to oak woodlands (North Coast

Regional Land Trust 2011). Research conducted in the Bald Hills of Humboldt County, 45 miles south of the study site, indicated that oak woodland communities have decreased by a third since 1850 and are expected to continue to decline (Sahara et al. 2015; Sugihara 1987). In the Little Bald Hills of Del Norte County, Jeffrey pine grasslands were also at-risk with roughly 40% of Jeffrey pine habitat loss to conifer encroachment since 1942 (Sahara et al. 2015). The study estimated that less than 5% of Jeffrey pine habitat is expected to remain within 50 years.

This study used dendrochronological and geospatial methods to answer the question: To what extent has the traditional cultural landscape at Mvs-yee-se'-ne changed since Euroamerican settlement circa 1850? Tribal members have observed that the grassland has shrunk and that invasive weeds, such as Himalayan blackberry (*Rubus armeniacus*), Scotch broom (*Cytisus scoparius*), and French broom (*Genista monspessulana*), limited accessibility as they become more prolific at the parcel (Suntayea Steinruck and Cynthia Ford, pers. comm. 2016 - 2019; Figure 3). Acorn crops were also frequently infested or produce low yields while poison oak and overgrown grass obscured the visibility of fallen acorns. The presumption was that these changes are primarily the result of twentieth century fire suppression policies in combination with extractive activities such as logging and mining.

Figure 3. Invasive weed patch adjacent to Oregon oak woodland. Photograph by Brandy Clark (2017).

1.1 Fire: Historical Context

The scientific community is generally in agreement that oak communities in this region, including Oregon white oak, flourished during the Holocene because of anthropogenic burning practices (Anderson 2013; Boyd 1999; Crawford et al. 2015). Oregon white oak is a fire-adapted species that is dependent on the benefits associated with periodic episodes of fire: fire restricts seedling establishment of competing species, reduces canopy closure, and has been shown to cause Oregon white oaks to emerge more rapidly (Cocking et. al. 2014 and 2015; Gucker 2007; Regen and Agee 2004). Fire also acts as a fumigant and direct mortality agent in controlling weevil infestation in acorns the year of and after burning has been conducted (Halpern 2016). Departures from historical fire return intervals are now being interpreted for pre-contact anthropogenic fire management across cultural landscapes and individual archaeological sites (Storm 2002; Taylor and Skinner 2003). Long-term deviations from formerly frequent fire regimes were widespread across the North American continent (Bakker, 2019; Copes-Geritz et al. 2017; Falk et al. 2011; Johnson 2016; Martin 2019; Swetnam et al. 2016; Whitehair 2018). These deviations have resulted in changes to forest tree species composition and structure that can be attributed to cessation of indigenous occupation and tribal stewardship as the result of American colonization, fire exclusion legislation and enforcement, among other forestry practices (Lewis 1973; MacDougall et al. 2004).

While the general public remains largely unfamiliar with the ecological benefits of fire, Tribes have continually reacted against narratives enforcing a paradigm of fire suppression (Heffner 1984). Many Tribal members and practitioners are intrinsically aware of the historical role fire had, and continues to have, in sustaining ecological diversity. Indigenous knowledge tells us that many plants [including hazel (*Corylus cornuta var. californica)*, willow (*Salix spp.*), beargrass (*Xerophylum tenax)*, and acorn-producing trees] require annual or biennial burning to continue to be productive (Peters and Ortiz 2010). Raish et al. (2005) differentiated between “fire use” and “fire management”, the former describing the intentional setting of fires for specific purposes while the latter refered to controlled use of wildfire for landscape-level maintenance.

Williams (2002) clarified this further by outlining eleven categories of fire use, including: hunting; crop management; insect collection; pest management; improving growth and yields of plants; fireproofing areas around settlements; warfare and signaling; economic “extortion”; clearing areas for travel; felling trees; and clearing riparian areas.

1.2 Research Questions

With these observations above in mind, three specific research questions were posited:

1. What are the predominant species of tree encroaching into open areas at Mvs-yee-se’-ne?
2. How much of the grassland has been lost since Euroamerican settlement?
3. What is the observed age distribution among encroaching species in relation to the age of the Oregon white oak stand?

To answer question 1, I mapped the composition of the forest structure by documenting tree species frequency and diameter for the Jeffrey pine grassland boundary where conifer encroachment was most visible. To answer question 2, I estimated the loss of open space for the period 1942 - 2016 by comparing vegetation cover and species differences visible in aerial imagery. Although prescribed fire has been used within the oak woodland to control conifer encroachment and enable Tribal gathering since 1996 (Figure 4, Appendix A), the Jeffrey pine grassland received limited management during this same period. Tribal efforts in the 1990's - 2000's to mow the grassland were somewhat successful in controlling brush and sapling abundance, but since then, a well-established conifer seed bank threatens to engulf the remaining open spaces at the site with each passing year. Therefore, the rapidly changing overstory conditions of the Jeffrey pine grassland served as a unique study area from which to evaluate landscape change at Mvs-yee-se'-ne.

Figure 4. Representative section of Oregon white oak woodland at Mvs-yee-se'-ne that has had prescribed burning since 1996 showing limited conifer encroachment. Photography by Brandy Clark (2016).

To answer question 3, I compared tree establishment dates from Oregon white oak and conifer species using dendrochronology to establish a baseline for understanding the parcel's current forest age structure. Dendrochronology has been used as an interdisciplinary tool to make informed interpretations of phenomena occurring at sites or in the larger region. Environmental interactions and reconstructions of pre-contact and historic landscapes, referred to as environmental archaeology or landscape archaeology, can reflect how forest dynamics are affected by human activity at archaeological sites (Fritts and Swetman 1989; Reiser 2010). Lastly, tree establishment dates were qualitatively associated with a series of successive midcentury aerial photographs to more closely relate conifer establishment with recent disturbance events occurring at the study site, namely timber harvesting activities.

This research contextualized these environmental shifts in forest structure to position current restoration projects happening at Mvs-yee-se'-ne within a paradigm of adaptive management. Studying historical change of Oregon white oak habitat as an effect of ecocultural adaptations has been advocated as an essential first step to mapping out restoration goals and strategies (Pellatt and Gedalof 2014, Whipple et al. 2010).

2.0 ENVIRONMENTAL STUDY AREA

Mvs-yee-se'-ne is located within the Smith River National Recreation Area (SRNRA) on the Gasquet Ranger District of the Six Rivers National Forest located in Del Norte County, California. Mvs-yee-se'-ne is situated on the Middle Fork of the Smith River near its confluence with the North Fork outside of the town of Gasquet, CA, at an elevation of approximately 300 meters above mean sea level (AMSL). The Smith River is the only undammed river in California from source to ocean. Its three main stems, along with numerous tributaries, support anadromous fish habitat for migrating populations of Chinook and Coho salmon, as well as Steelhead and Coastal Cutthroat trout (Six Rivers National Forest 2018). The parcel is a flat, uplifted alluvial terrace with two seasonal drainages and an annual drainage which informally separates the oak woodland from the grassland (Figure 4). Precipitation is high, averaging 230 cm (~90") annually, which causes intermittent flooding of low-lying areas (Smith River Alliance 2018).

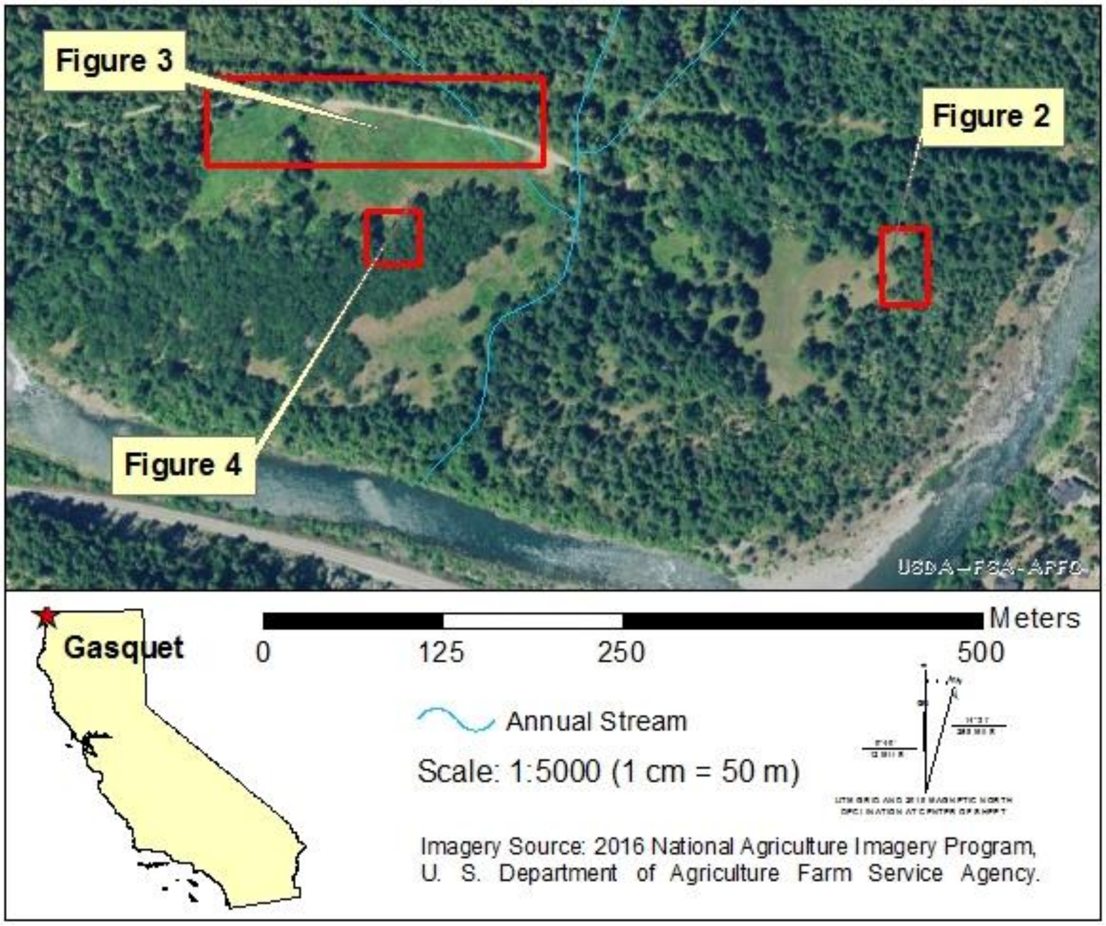

Figure 5. Present day [2016] Mvs-yee-se'-ne near the Smith River showing areas of Jeffrey pine grassland (Figure 2), invasive weed patch (Figure 3), and Oregon oak woodland (Figure 4).

2.1 Vegetation and Traditional Ecological Resources

The Jeffrey-pine grassland at Mvs-yee-se’-ne is a distinct landscape endemic to the area with understory species such as Idahoe fescue (*Festuca idahoensis*) and manzanita (*Arctostaphylos manzanita ssp*). This terrain type is an indicator of underlying nutrient-deficient serpentine soils that can harbor economically important mineral deposits (Whittaker 1960). Geologic process occurring on the SRNRA, such as tectonic uplift and prolonged erosion, have created these types of complex environments which are situated between the Franciscan metasedimentary rocks of the Coast Range Geomorphic Province and the Josephine Ophiolite of the Klamath Mountain Geomorphic Province. The result is a variety of bedrock materials that support a diverse array of plant communities as well as concentrations of minerals such as gold, chromium, and copper that have been exploited historically for their economic value (Cater and Wells 1953).

Mvs-yee-se'-ne is also considered a cultural landscape because of the dense amount of traditionally-used-species that continue to be harvested by Tribal members. Aside from pine nuts and acorns (white and tanoak [*Notholithocarpus densiflores*]), other on-site vegetation contributes to edible, medicinal and utilitarian traditional uses such as red and evergreen huckleberry (*Vaccinunium spp*.), wild strawberry (*Fragaria californica)*, thimbleberry (*Rubus parviflorus*), trailing blackberry (*Rubus ursinus*), Pacific madrone (*Arbutus menziesii*), manzanita, yerba buena (*Satureja douglasii*), brodiaea bulbs, peppernuts (*Umbellularia californica*), and hazel nuts. For example, hazel is known for its use in basket-making enterprises (Peters and Ortiz 2010). Other weaving materials on site consist of pine root, string iris (*Iris macrosiphon*), alder bark (*Alnus spp.*), Oregon grape (*Berberis nervosa*), soaproot (*Chlorogalum spp.*) and various ferns and mosses. Medicinally, herbs such as yarrow (*Achillea spp.*), wood sorrel (*Oxalis suksdorfii*), and Labrador tea (*Ledum spp.*) complement the holistic properties of the other species listed above (Baker 1981). Terrestrial and aquatic resources present include deer, bear, small game, and fish which provide additional nutritional opportunities while also contributing to utilitarian needs.

2.2 Cultural and Historical Context

Since time immemorial, the Dee-Ni' people (Tolowa) have inhabited the Smith River basin, represented today mainly by the federally recognized Tolowa Dee-Ni' Nation (formerly the Smith River Rancheria), Elk Valley Rancheria, and the federally unrecognized Tolowa Nation. In 1862, the Smith River Reservation was established, but was abandoned in 1868. The Smith River and Elk Valley Rancherias were established under the Landless Indians Act of 1906, terminated in 1960, and reestablished following the 1983 Tillie Hardwick case. Today, the distribution of members continues to be connected to locations of traditional villages from Wilson Creek to the Smith River and northwards into southern Oregon, although the historical legacies of forced removal, family separation, and persistent resilience places Tolowa descendants across the nation.

Tushingham presented a comprehensive timeline that positions Tolowa cultural history within accepted chronologies of the archaeology and paleoenvironment of northern California and the Pacific Northwest, from the Late Pleistocene to the historic era (Tushingham 2013). Tushingham is one of the few published researchers who has delivered contemporary archaeological interpretations regarding Tolowa material culture outside of environmental compliance reports since mid-century work conducted by Gould

(Tushingham 2009 and 2013; Tushingham and Bencze 2013; Tushingham and Bettinger 2014; Tushingham et al. 2018; see also Connolly 1988; Gould 1972 and 1975). Tushingham's research, 10 miles downriver at Chvn-su'lh-dvn, is particularly significant for documenting an extremely long occupational history of upriver Tolowa spanning 8,500 years that revealed some of the earliest plank houses, the only semi-subterranean sweathouse recorded to date in northwestern California, and the earliest evidence of tobacco smoking on the Pacific Northwest Coast (Tushingham 2009; Tushingham 2013).

While Mvs-yee-se'-ne was definitively inhabited at the time of Euroamerican contact (Keter 1993), it is unclear how long the parcel was occupied prior to the Dee-Ni' Holocaust that began circa 1851 with the "Burnt Ranch Massacre" at Yontocket (Gould 1966; Tolowa Dee-Ni' Nation 2011). However, Tushingham's work at Chvn-su'lh-dvn offered a reasonably comparable illustration of the deep-rooted Gee Dee-Ni' and Da'-chvn-dvn Dee-ni' [upriver Tolowa] settlement patterns that contrast Gould's assertions that such places were inhabited only seasonally (Gould 1972; Gould 1975).

The first historical document to record non-indigenous land use of the parcel is a General Land Office (GLO) homestead patent deeded to Laurent Bonnaz for 146 acres in January 1890 (Conners 1992). Bonnaz is later identified as married to an indigenous woman, referred to by her anglicized name "Flora" (comm. Loren Bommelyn, in Conners 1992). When or how they came to reside upon the flat is unknown, but by 1909 Mary Adams Peacock had bought the property from Bonnaz. Little documentation recorded how the property was used during this period, although a number of relatively olderlooking fruit trees are still present. When Mary Adams Peacock passed, the parcel was sold at auction to John Pappadopolous [Pappas] and Peter Stathes in 1943. It is unknown whether any of these historic figures actually resided on the parcel, or if the parcel was used solely for commercial and recreational purposes.

This thesis does not attempt to contextualize the parcel in the same manner as Tushingham. More emphasis was placed upon recent history, beginning around the era of permanent Euroamerican settlement, circa 1850, and how the sudden, violent removal of indigenous Tolowa has contributed to changes in the cultural landscapes at Mvs-yee-se'-ne. After acquiring the property in 1989, the U. S. Forest Service began burning the oak woodland in 1996. National Environmental Policy Act (NEPA) documents indicated that the age and the health of the oak woodland were to be determined by specialists; however, it seems that data was never acquired or has been lost in the ensuing years.

3.0 METHODS

3.1 Field Mapping

Between July and September 2018, all live and dead trees above 5 centimeters in diameter that were within 10 meters of the Jeffrey pine grassland boundary were mapped using a Global Positioning System (GPS) unit and their outer-bark diameters were measured at breast height (dbh) using a standard logger's tape. Diameter measurements were taken in inches rounded to the nearest tenth and converted to metric dimensions. A total of 1211 individuals were plotted using a combination of three different geographic positioning systems: 1) a Garmin GP 62 (793 individuals); 2) Avenza Maps iOS application deployed on an iPad Mini 4 (264 individuals); and 3) a Trimble GeoXH running ArcPad 10.0 (154 individuals).

Locational accuracy varied across the three devices. The Trimble and Garmin had higher degrees of accuracy (3 - 9 meters), although the Trimble was less accurate in forested conditions. The Avenza app had accuracy estimates of 10 - 30 meters. All GPS points were projected in the 1983 North American datum (UTM NAD 1983 Zone 10T) and input into a geodatabase in ArcMap 10.5.1. Field notes were added to the attribute table in ArcMap and designated if a tree was live, dying, dead, a stump, or if an accurate dbh was obstructed due to heavy poison oak. Because of heavy poison oak, diameter was approximated for 35 trees using visual estimates of nearby measured trees.

3.2 Dendrochronology and Tree Establishment Dates

Annual tree growth is known to be variable from species to species and across individual specimens of the same stand (Cook and Kairiukstis 1989; Speer 2010). This variability is dependent on limiting factors of local ecological influences such as water availability, stand density, soil type, climate fluctuations, and stand disturbance which can affect both vertical (primary) and lateral (secondary) development. Secondary growth forms the basis for tree-ring dating and occurs in the cambium, which is a layer of generative tissues that regenerates on a biannual basis forming lighter rings of earlywood and darker rings of latewood, also referred to as springwood and summerwood (Speer 2010:87). It was thus necessary to take multiple samples across the site to assess average growth patterns for cross-dating, as well as to avoid basing dates on outliers or individual discrepancies (Cook and Kairiukstis 1989:28).

Tree ages were obtained from a subsample of live trees from December 2018 to March 2019 using 5.15 mm wide Haglof increment borers. All sampled trees were single-stemmed, and core height was generally one meter from the ground surface, but varied occasionally due to branches, brush, or stem defects. Fifteen tree cores per species were retrieved from 3 types of conifer around the edge of the Jeffrey pine grassland and Oregon white oak within the woodland. In total, a subsample of 60 trees over 7.5 cm in diameter were systematically selected by dbh class for coring. This sub-sampling strategy was conservative in the amount of specimens sampled compared to the population due to commitments made to Tribal partners to impact the minimum number of trees necessary to complete the study. In this study, the two distinctly different areas of Mvs-yee-se'-ne were sampled to compare age distribution between encroaching species and Oregon white oaks.

Jeffrey pine grassland

For the Jeffrey pine grassland, trees selected for coring were randomly chosen from GPS points taken while mapping the grassland by executing the 'Create Random Points' tool in ArcMap 10.5.1. Mapped GPS points were first filtered by their tree species, from which the three most prevalent species along the grassland boundary were selected for age assessment (Table 1). Trees less than 7.5 cm in diameter, stumps, dying or dead trees, and trees with heavy poison oak were removed from the analysis as viable trees for conifer core sampling (n = 263). In total, 948 trees within the grassland were considered viable for coring. A random stratified sample of fifteen points was generated separately in ArcMap using the natural breaks function to determine size classes for the three most predominant species: Douglas-fir, incense cedar, and yellow pine (yellow pine included Jeffrey pine and Ponderosa pine trees). All cored trees had their diameters measured at core height prior to coring.

Oregon white oak woodland

To select a subsample of trees for coring within the more open oak woodland, aerial imagery from 2016 USDA Farm Service Agency's National Agriculture Imagery Program (NAIP) was loaded into ArcMap to determine the approximate area covered by the oak woodland. A polygon was digitized around its outer boundary and the 'Create Random Points' tool in ArcGIS was utilized to generate random points among five size classes within the woodland polygon; size classes were split evenly between 0 cm and the maximum allowable core to be retrieved by the borers available (approximately 76 cm). The closest Oregon white oak adjacent to the randomly generated point and within the selected size class was cored. All cored trees had their diameters measured at core height prior to coring.

3.3 Laboratory Methods

Core samples were dried, mounted, and sanded to count rings under a dissecting microscope to determine the pith year or earliest year of growth sampled. If the pith was not present, the innermost ring was used as a minimum age count, and years to pith was estimated if possible (Duncan 1989). Cores missing the pith by more than 10 years were also considered minimum age counts. The number of years to coring height was not estimated. Conifer species were only visually dated due to time constraints. Oregon white oak samples were also visually dated, followed by computerized measuring using the program WinDendro to refine the accuracy of their ring-width measurements (WinDendro software, Regent Instruments, version 2014). Decadal ring-width measurements were statistically cross-dated using COFECHA which calibrates the variation in annual ring widths across a sample population (COFECHA software version 6.02P, Richard Holmes 1983).

Linear regression equations of age and diameter were calculated for each species using samples where the pith was present or estimated within 10 years as described above. Pearson's correlation coefficient (r) and coefficient of determination (R^2) was compared for each species as an indicator of positive or negative association between age and diameter for trees growing at the site (Appendix C). If the relationship between age and diameter was statistically significant for a species, the linear regression's intercept equation was applied to the diameter of a non-cored tree at the site to estimate the overall range in ages for the species at this location.

3.4 Image Classification

Aerial photographs of the study area were acquired through the Six Rivers National Forest for the years 1942, 1960, 1968, and 1970. An additional aerial photograph was acquired from the California Department of Forestry (now CalFIRE) for 1948, and a NAIP image for 2016 was used to evaluate current conditions. Attempts to acquire timber-harvest plans from CalFIRE for the parcel were unsuccessful. Aerial photographs were digitally scanned to 600-dpi and georeferenced into ArcMap (version 10.5.1) using the 1983 North American Datum projection (NAD 83 UTM Zone 10T). Each photograph was visually inspected to document landscape change for the period between photograph series. Variations in vegetation cover related to the size, shape, and patterning of coverage types were documented and associated with other alterations to the landscape including the addition or modification of utility lines, transportation routes, and skid trails used during timber operations. However, the classification analysis was performed only on the earliest (1942) and most recent (2016) aerial photographs.

Loss of open space since 1942 was estimated for the grassland area using a simplified version of the image classification model employed to predict Jeffrey pine savanna loss in the Bald Hills (Sahara 2012; Sahara et al. 2015). Vegetation in each aerial photograph was grouped in ArcMap using the interactive supervised classification function which associates a pixel's red-blue-green (RGB) color variation with user-defined "training areas" where vegetation type is known. Fifteen training areas were identified and ground verified for each class based upon personal knowledge of the site. Three classification groups were used: grassland, tree canopy, and shadow. Classification outputs were converted from raster to vector formats using the 'Raster to Polygon' tool and acreage was calculated for each class for both photograph years.

4.0 RESULTS

4.1 Tree Size Structure

The current Jeffrey pine grassland edge was overwhelmingly comprised of small diameter conifers, which were predominantly represented by Douglas-fir and incense cedar. Eighty-percent of mapped trees (n = 857) were either Douglas-fir (430) or incense cedar (427). Furthermore, the stand structure had trees almost entirely represented by dense accumulations of pole-sized trees with 79% of trees less than or equal to 30 cm (n = 952). Ninety-two percent of incense cedar trees (393) were less than 30 cm in diameter (393). Sixty percent of Douglas-fir trees (260) were less than or equal to 30 cm in diameter. Douglas-fir was well-represented across the parcel, while incense cedars were primarily on the eastern and southern aspects in primarily rocky substrates (Figure 7). Other tree species occupied a relatively low percentage of cover (266 or 22% of all trees; Table 1 and Figure 6).

Table 1. Number of individual specimens (NISP) [1] plotted along the Jeffrey pine grassland boundary among 10 cm size intervals.

	>10	**>20**	**>30**	**>40**	**>50**	**>60**	**>70**	**>80**	**>90**	**>100**	**>110**		**NISP**
ALD	1	4	12	1	0	0	0	0	0	0	0		18
DF	95	92	73	60	45	30	19	8	4	3	1		430
FRT	1	0	1	0	1	1	0	0	0	0	0		4
IC	185	151	57	15	10	8	0	1	0	0	0		427
LO	25	15	3	3	0	0	0	0	0	0	0		46
MD	30	32	16	4	2	1	0	0	0	0	0		85
MZ	9	1	0	0	0	0	0	0	0	0	0		10
OTH[2]	3	11	1	1	0	0	0	0	0	0	0		16
WO	0	1	1	0	0	0	0	0	0	0	0		2
POC	0	0	1	1	0	0	0	0	0	0	0		2
PW	0	1	0	0	0	0	0	0	0	0	0		1
SP	0	0	1	0	0	0	0	0	0	0	0		1
TO	54	13	5	6	2	1	0	0	0	0	0		81
YP[3]	12	23	22	20	6	1	3	0	0	0	0		87
NISP	415	344	193	111	66	42	22	9	4	3	1		1210

1 Species codes: ALD (*Alnus rhombifolia*, White alder); DF (Douglas-fir); FRT (Non-native domesticated fruit); IC (Incense cedar); LO (*Quercus agrifolia*, Coast live oak); MD (Pacific madrone); MZ (manzanita); OTH (Other); WO (Oregon white oak); POC (*Chamaecyparis lawsoniana*, Port-Orford cedar); PW (Pepperwood [California Bay laurel]); SP (*Pinus lambertiana*, Sugar pine); TO (*Notholithocarpus densiflorus*, Tanoak); YP (Yellow pine)
2 Includes Jeffrey pine and Ponderosa pine. Some trees were difficult to identify in the field and have been combined here.
3 Possible introduced, invasive, or other domesticated species.

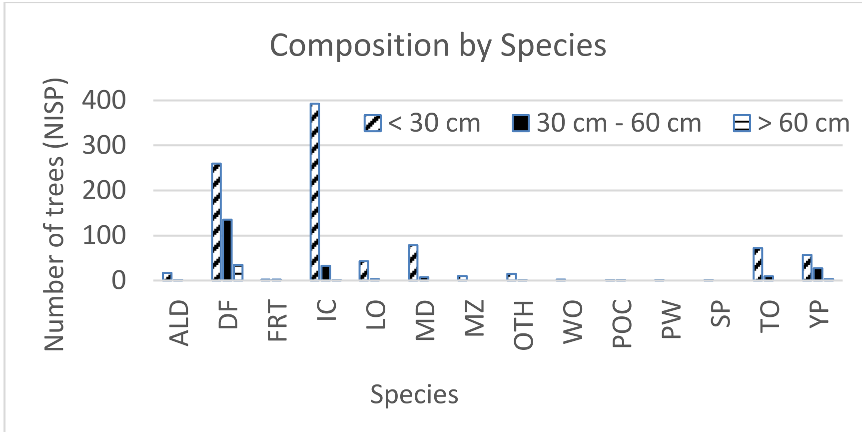

Figure 6. Number of individual specimens (NISP)[1] by species and relative size. See Table 1 for species abbreviations.

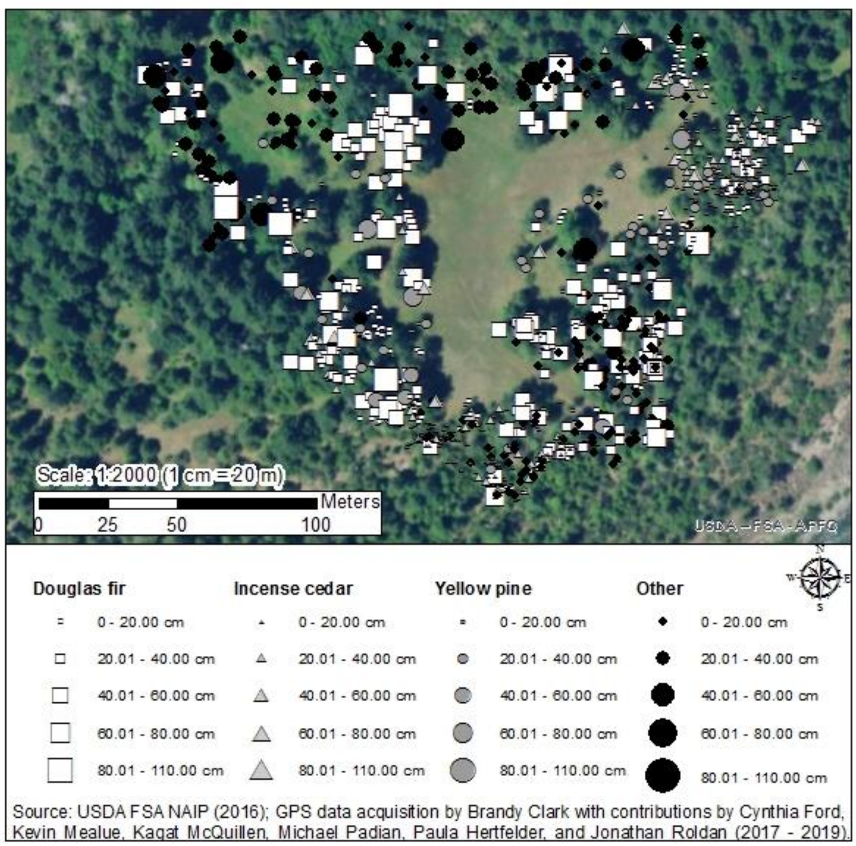

Figure 7. Spatial distribution of trees along Jeffrey pine grassland boundary.

4.2 Oregon White Oaks and Conifer Tree Ages

In total, 15 Oregon white oak and 46 conifer trees were cored. Of the 61 trees cored, 26 trees included the pith. The pith was estimated up to 10 years for 20 trees. Two white oak trees had pith estimates greater than 10 years and were not considered reliable age estimates. Distance to pith was not calculated for 13 trees due to ring irregularities or broken cores. Tree ages (at coring height) ranged from 21 years (yellow pine, dbh =11.94 cm) to 209 years (Oregon white oak, dbh = 69.6 cm). The oldest tree was also the largest diameter white oak.

The mean age (at coring height) for Douglas-fir was 54.8 years (range of 28 - 97 years); the mean age for all cored yellow pine was 55.92 years (range of 22 - 144 years); and the mean age for all incense cedars was 51.42 years (range of 27 - 82 years). By comparison, the mean age for all of the cored Oregon white oaks was 158.85 years (range of 120 - 209 years). No white oak establishment occurred after1908, but this observation may be an artifact of the conservative sampling strategy. For conifers, relationships between tree age and dbh were not significantly correlated at the study site (Figures 7a-c). In contrast, the relationship between dbh and age for cross-dated Oregon white oaks was significant with an R^2 value of .83 and a p value of .004. All except two of the cored Oregon white oaks were reliably cross-dated (Figure 8).

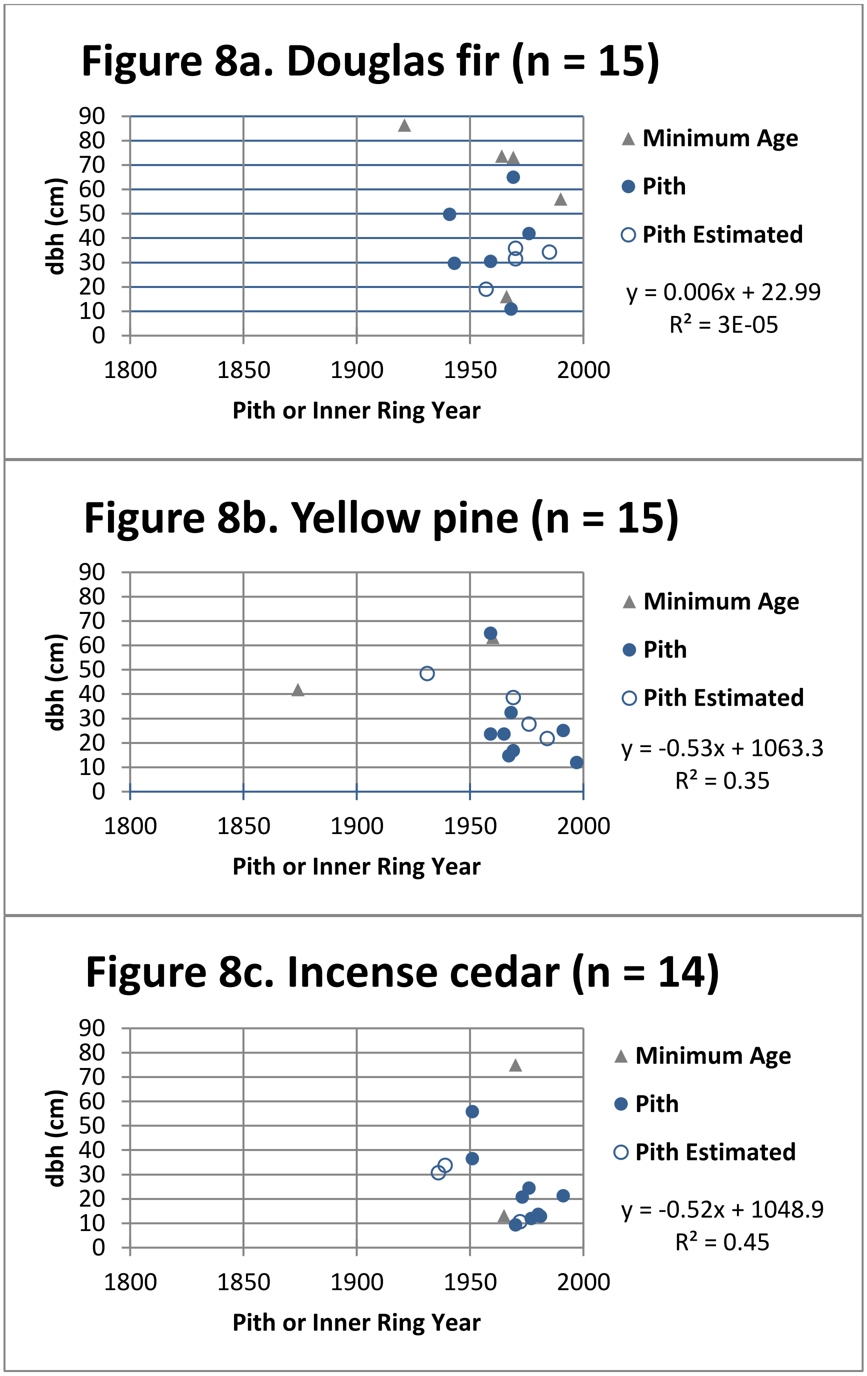

Figure 8a-c. Correlation between age and diameter in cored a) Douglas-fir, b) yellow pine, and c) incense cedar. Mean estimated age was 59 years, 56 years, and 51 years.

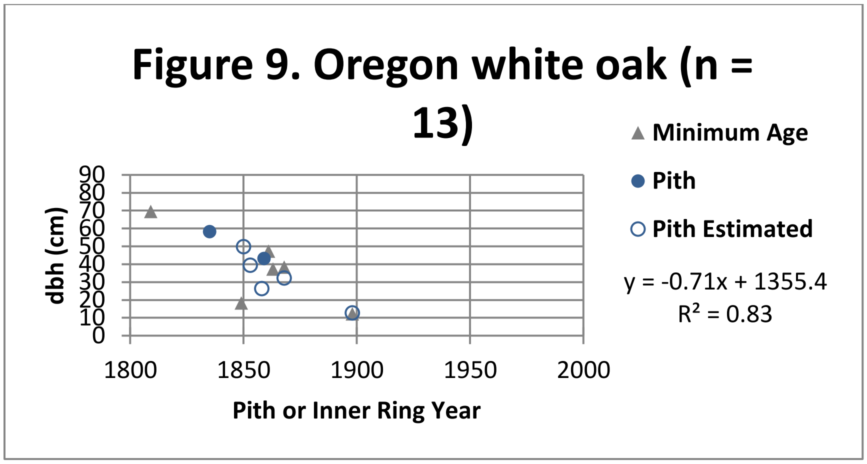

Figure 9. Correlation between age and diameter in cross-dated Oregon white oak trees. Mean estimated age was 158 years.

4.3 Jeffrey Pine Grassland Loss

Classification results

Classification results indicated that in the 76 years since the earliest aerial photo was taken, over 50% of the grassland at Mvs-yee-se'-ne has converted to a Douglas-fir/conifer dominated stand type (Figure 9). This ratio was based on the number of pixels for each class relative to the total number of pixels in the output. In 1942, grassland covered 6.5 acres of the eastern portion of the parcel, tree canopy covered 11.3 acres, and shadow covered 1.4 acres of pixel exposure. In 2016, grassland was reduced to 3.4 acres, tree canopy coverage increased to 14.4 acres, and shadows remained at 1.4 acres of pixel exposure.

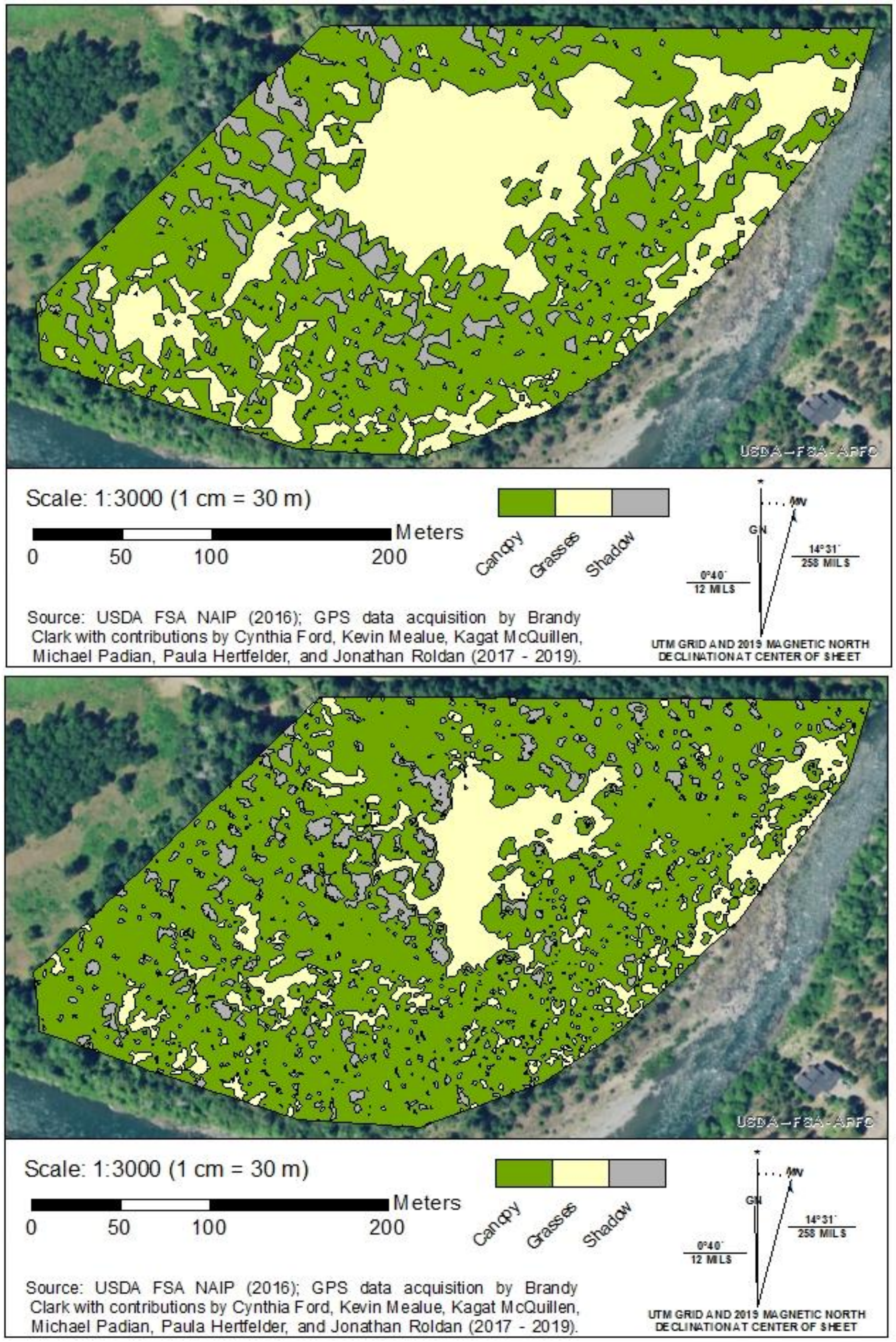

Figure 10. Supervised classification results for 1942 (top) and 2016 (bottom); 3.1 acres of grassland has converted to canopy in 74 years.

Midcentury logging events and current landscape conditions

Visual analysis of aerial images documented numerous logging events at the site between 1942 and 1970. A relative timeline of logging events is presented to contextualize landscape differences visible in successive aerial photographs. The earliest known aerial photograph of the parcel was taken in 1942 (Figure 10). By 1943, owners Pappadopolous [Pappas] and Stathes bought the property at auction. Pappas and Stathes were listed in Crescent City residential directories as early as 1936 - 1937; by 1940, census documents record Pappas owned a retail wood yard. Keter alluded to their operations by claiming that Pappas was "…buying up all the timbered parcels in this region for a consortium who were investing in land for the purposes of harvesting commercially viable stands of timber" (Keter 1995:58). It is unknown whether either owner was directly involved in logging operations at Mvs-yee-se'-ne, but Metsker's maps of Del Norte County from 1949 confirmed Keter's assertions that Pappas and his wife owned several parcels within the county (see T 15N, R 1 E, Sec. 18, 24; T 16N, R 1 E, Sec. 36; 17N, R 1 E, Sec. 17).

Between 1942 and 1948, portions of the original conifer stands flanking the Oregon white oak woodland to the north, northeast and southeast were logged but some large diameter trees remained intact in these same areas. The annual drainage was discernible due to the removed canopy and may have been used to skid logs. Logging was not yet visible within the eastern grassland (Figure 11). The powerline and road into the flat were also visible by 1948.

Figure 11. Detail, aerial photograph DCK-2-34, September 11, 1942. Earliest known aerial photograph of Mvs-yee-se'-ne.

Figure 12. Detail, aerial photograph CDF 2-20-79, June 23, 1948.

The timber extraction operations visible in the 1948 photograph appeared to be more consistent with selective harvesting techniques. These may have been the product of multiple factors influencing forestry practice post-WWII including: increased but still limited mechanization by heavy equipment that became more popular starting in the late 1940's (Bearss 1969); selection methods which favored retention for economic as well as regeneration purposes (Curtis 1998); and a slow rate of improvement in the timber market that had yet to reach peak demand (Haynes 2008:18). By 1960, areas logged in the 1940's photographs were essentially clear-cut of any remaining timber (Figure 12). Similarly, the sloped areas to the north of the flat were logged but still confined to the west of the Jeffrey pine grassland. The road system became more developed and began to traverse through the grassland. Utility infrastructure also expanded with a larger transmission line located north of the original line.

Simonson, a local logger, acquired partial interest in 1962 (Conners 1992). The 1968 aerial photograph was at larger scale resulting in a lower resolution than the others (Figure 13). However, it was apparent that by 1968, additional timber was removed from the eastern and northern portions of the parcel. Effects to the landscape were more evident by 1970: some of the logged areas had heavily reseeded, particularly in the northeastern most section of the flat (Figure 14). Since then, young dense stands of timber have reestablished in heavily logged areas across the flat (Figure 4). Excavator piles, temporary roads, and former landings were also still present, albeit now overgrown.

Figure 13. Detail, aerial photograph EII-1-152, August 6, 1960.

Figure 14. Detail, aerial photograph, EVZ-1-98, July 7, 1970.

After acquiring the property in 1989, the U. S. Forest Service again logged the area north of the Oregon white oak woodland in 1996 in an effort to release the oaks while also collecting a commercial byproduct. Since then, this area has become heavily overgrown with invasive species (French broom and Himalayan blackberry) amounting to a nearly inaccessible 3-acre portion of the site (Figure 2).

5.0 DISCUSSION

5.1 Landscape Change at Mvs-Yee-Se’-Ne

In answering the initial question, to what extent has the Tolowa traditional cultural landscape at Mvs-yee-se’-ne changed since Euroamerican settlement circa 1850, this thesis showed that an established stand of Oregon white oaks was present at the time of Euroamerican contact circa 1850. It is difficult to know exactly how the landscape appeared at the time of contact. However, this study documented loss of open space, while also providing baseline data from which to inform current and future management strategies. Oral histories from Tribal leaders with knowledge of the parcel’s ecological and cultural significance indicated the woodland was planted and maintained immediately preceding and around the time of contact (John Green, pers. comm. 2017). During this time, access to other gathering places was increasingly limited by threats from miners and settlers. The data gathered for this thesis appears to potentially support this traditional knowledge. For example, of the 7 cross-dated oak samples that had counts to pith or reasonable pith estimates, 5 tree ages (at coring height) dated to the 20-year period from 1849 - 1869. It is unknown how many years it took the trees to grow to coring height (around 1 m high), but took likely no more than 10 years prior to the coring height pith dates (R. Sherriff, pers. comm. 2020). While these results are promising, additional dendrochronological sampling of Oregon white oaks needs to be performed to confirm whether or not the statistical significance was inflated due to the small sample size. Other studies found less consistent relationships between age and diameter in Oregon white oaks locally (Schriver and Sherriff 2015; Schriver et al. 2018).

The image classification results, combined with the mapped trees, provided data to answer questions 1 and 2. For the current grassland boundary substantial conifer encroachment was present: 78% of the trees (n = 952) measured along the grassland boundary were under 30 cm in diameter. Yellow pine continued to establish successfully in the grassland, but is being replaced by Douglas-fir and incense cedar (Table 1). The loss of nearly 50% of the open Jeffrey pine grassland at Mvs-yee-se'-ne is consistent with findings from another study conducted in Del Norte County reporting similar results (Sahara 2012; Sahara et al. 2015).

Data acquired to answer Question 3 indicated Oregon white oaks have been present at Mvs-yee-se'-ne since at least 1809. Since diameter and age were determined to be highly correlated for the species at this location, an estimate was generated for tree ages of uncored white oaks. Larger Oregon white oaks existed within the woodland, some in excess of 80 cm in diameter, and can reasonably be expected to be older than the dated trees. Based on the age-diameter relationship from cored oaks, an Oregon white oak at Mvs-yee-se'-ne with a diameter of 80 cm could have established at or before 1800. No other species on site reached a similarly mature age, although conifers were removed during repeated logging harvests conducted during the middle of the twentieth century.

Similar temporal patterns of oak establishment occurred in Humboldt and Mendocino counties, where most oaks stands initiated within a relatively narrow period of time in the mid-to-late nineteenth century (Schriver and Sherriff 2015; Schriver et al. 2018). They assumed this pattern may have resulted from an unknown stand-level disturbance - such as fire, grazing, or reductions in anthropogenic burning - or to favorable climate conditions, which promoted tree establishment. Comparable recruitment patterns occurred in Oregon, where most surviving Oregon white oaks in their study areas established circa 1850 - 1890 (Gilligan and Muir 2011); they described this as consistent with a pulse of regeneration of the species across its range during that period. They attributed this flush in recruitment to a number of possible factors: the cessation of Native American burning regimes, which could have allowed increased survivorship of oak seedlings in formerly frequently burned oak savanna; the introduction of Euroamerican livestock as a vector of spreading and fertilizing acorns; or a return to wetter and cooler conditions following a period of drought circa 1815 - 1850 (Gilligan and Muir 2011:154). Since scientific explanations for increased oak establishment during this period are still speculative, the oral history of Tolowa Tribal leaders can also be seen as an explanation for the observed increase in establishment of oaks along the northwestern coast of the United States of America during this same time. It is likely that many factors contributed to this brief but important period of oak resurgence.

A similar pattern of conifer establishment has been documented across northwestern California comparable to results from Mvs-yee-se’-ne, with most Douglas-firs establishing after 1950. These findings were consistent with age distributions in conifer-encroached Oregon white oak ecosystems (Schriver et al. 2018). Unlike the

Oregon white oaks, conifer ages at the site could be estimated by their diameter. Douglas-firs had the widest range of variability. For example, two trees of similar diameter had ages circa 1941 and circa 1990.

Midcentury logging had the most dramatic direct and indirect effects to the landscape at Mvs-yee-se'-ne. While decreases in the size of prairie and savannah ecosystems can be attributed to reductions in anthropogenic uses of fire, common to the area and fully suppressed by the turn of the twentieth century, loss of open space at Mvs-yee-se'-ne has been catalyzed by repeated logging events that favored Douglas-fir reproduction. Douglas-fir establishes best on mineral soil, where high yields will naturally stock post-harvest in places where mineral soil is fully exposed (Uchytil 1991). Dendrochronological sampling of the conifers surrounding the Jeffrey pine grassland recorded an intense establishment of conifers coincident with a time of known logging occurring during the 1950's and 1960's. The result is that the former relatively open Jeffrey-pine grassland has become heavily fragmented.

Mapping results provided further visualization of encroachment patterns and trends among species (Figure 7). Current areas that are densely overgrown can be zones of high priority for hazardous fuel removal to a) reduce the risk of developing crown fires, and b) reduce the seed bank to diminish stand-replacement by Douglas-fir and other conifers. Mapping the distribution of stumps on site would aid in field verification of the image classification to better understand the boundary of where the grassland originally existed prior to logging events that began taking place mid-century. This would also be useful for distinguishing the type and distribution of trees along the boundary prior to logging. It was inferred that those trees were mature populations of Jeffrey pine or Douglas-fir trees due to their wide spacing and large crowns visible in the 1942 aerial photograph (Figure 10).

5.2 Management Implications

This study, in combination with long-standing local observations and other research, has noted that ongoing environmental shifts and changes in how humans use these landscapes resulted in open-area conversion to closed canopy environments. This thesis analyzed the historical legacies that have contributed to landscape change at Mvs-yee-se'-ne, while providing data that can be used for adaptive management strategies.

Ideally, adaptive management relies on a model of trial-and-error with purposeful intent to determine better methods by which to conduct ecological restoration objectives (Stankey et al. 2005:9). This occurs through a mutually reinforcing cycle of planning, action, monitoring, and evaluation that relies on an explicitly scientific structure of hypothesis testing, replication, and assessment (Figure 14). Ecological restoration was cited by the U. S. Forest Service as "the central driver of wildland and forest stewardship in the Pacific Southwest Region [i.e., California], across all program areas and activities…" (USDA 2015); adaptive management was one of the primary strategies being used to reestablish resilient forest ecosystems (USDA 2015:11).

Figure 15. Image in Adaptive Management of Natural Resources: Theory, Concepts, and Management Institutions. Gen. Tech. Rep. PNW-GTR-654. (Stankey et al. 2005).

Prescribed fire objectives initiated for Mvs-yee-se'-ne over 30 years ago are now at the evaluation phase of the adaptive management cycle, which elucidate whether the project successfully met the purpose and need of its outlined goals. Bridging the gap between the original (1995) objectives for restoration with observations made since then, including those presented here, can lead land managers and Tribal partners to develop future planning and action. Although federal land managers are being allowed to conserve the physical and intangible integrity of cultural landscapes with low-severity prescribed burning (Dyer and Constan 2014; Dyer et al. 2018), this study has shown that the pace and scale of current restoration efforts is insufficient in its existing form to adequately address the threat of conifer encroachment.

At first glance, managing cultural resources provides a seemingly atypical opportunity for employing adaptive management theories. However, when adaptive management was compared against philosophies promoting traditional ecological knowledge (TEK), parallels were found in that each paradigm emphasizes strategic, interdisciplinary planning for future ecological possibilities (Berkes et al. 2000; Houde 2007). Making use of multiple knowledge systems - such as integrating conventional science with TEK and Tribal values - allows for a deeper understanding of landscapes as socioecological products that simultaneously shape and are shaped by human interaction (Lake 2013; Lake and Long 2014; Hummel and Lake 2015; Lake et al. 2018).

Furthermore, acknowledging colonial features and other historical precedents - such as overlapping tenure and property rights, land use practices, fire suppression and exclusion, industrial forest management, or top-down decision-making approaches and structures - within current restoration approaches allows partners to overcome assumptions and biases about how landscapes should be managed and where a zone of agreement can be reached (Copes-Geritz 2017; Lake et al. 2018). We can posit the question: what are we restoring and for whom (Boedhihartono and Sayer 2017)? Using a multi-methodological approach, this thesis provided some evidence for showing that there have been long-term environmental consequences resulting from historical legacies such as twentieth century logging activities and fire suppression at Mvs-yee-se'-ne.

Changes in habitat composition resulting from landscape change can affect the effectiveness of prescribed fire ignitions (Agee 1996). Whereas a traditional fire return interval of 2 to 5 years may have been successful in generating brush-free stands composed of larger, fire-resistant trees, the introduction of broom species (Scotch and French), non-native grasses, and domesticated plants [such as Himalyan blackberry, English ivy, and Tree of Heaven (*Ailanthus altissima*)], require more frequent fire intervals initially to eliminate these competitors prior to returning to historic fire regimes. Mvs-yee-se'-ne has nearly all of these introduced species present. Caution is also warranted when planning for an uncertain future, as idealizing narrow windows of historical conditions may not be congruent with current and future environmental conditions (Long et al. 2018); rather, the ultimate goal should be creating resilient landscapes where fire is allowed to function (Lake and Long 2014:149).

Adapting management strategies now to more closely align with traditional burning schedules can curtail the observed occurrences of encroachment presented in this thesis, while also addressing the ecological and cultural ramifications of habitat loss that may have an effect on the cultural landscape at Mvs-yee-se'-ne in the future as climates continue to change. Increasing wildfires, intensification in competing land uses, pathogen, and the limited adaptive capacity of niched ecosystems all have the potential to directly impact the environment like that found at Mvs-yee-se'-ne (Bachelet et al. 2011;

Case and Lawler 2016; Huntzinger 2003; Odion et al. 2004; Pellatt et al. 2012). Environmental impacts have socioeconomic repercussions as well including loss of traditional food sources, the inability to adequately provide for traditional activities or ceremonies, and sovereignty concerns (Guyot et al. 2006, Ortiz 2008). Negative impacts to Tribal sovereignty can occur as the legal landscape is reshaped to account for species displacement as traditional territories are physically altered (Norgaard 2014). Limitations placed upon species quality or abundance may also lead to increased competition as resource scarcity persists or expands. Proactive strategies developed now can help alleviate some of these anxieties into the foreseeable future.

Incorporating traditional ecological knowledge into the adaptive management process is thus essential to realigning restoration strategies at Mvs-yee-se'-ne especially since the location was one of the first to be nationally recognized under Criterion A for the significance of its ecocultural landscape qualities (Keter 1993). While the current prescription may be adequate for limiting Douglas-fir encroachment into the Oregon oak woodland, it is not frequent enough to curtail reseeding by invasives (Lisa Hoover, USFS Six Rivers Forest Botanist, pers. comm. 2018; Figure 2), nor does it address maintaining the integrity of the parcel's environmental setting as a whole. It could be argued that this failure to adequately manage the entirety of character defining features at the cultural landscape is inconsistent with federal direction in the Forest Service Manual (FSM) requiring accordance with National Park Service standards (FSM 2364.42 & FSM 2364.41f).

6.0 CONCLUSIONS

This study found that Oregon white oaks have been present at Mvs-yee-se’-ne since at least 1809. Aerial images available from the 1940’s captured a landscape different from that shown in present-day satellite imagery. In those early photographs, an expansive grassland with wide-spaced trees stood in contrast to the overcrowded stands currently extant. GIS image classification analysis estimated that nearly 50% of the grassland habitat has converted to forested canopy since 1942. Extractive activities, primarily logging, were visible in aerial images taken in the decades between the earliest aerial images and present-day. It was assumed that these repeated logging events were responsible for the visible encroachment of small-diameter conifers represented in the grassland mapping data.

California is at risk of losing 750,000 acres of oak woodland by 2040 (Gaman 2008), and the management of legacy oak stands and grassland habitat like those found at Mvs-yee-se’-ne is critical to strategically sustaining native oak woodlands. Conifer encroachment within the oak woodland was reduced through the use of prescribed burning. However, conifers and invasive species were allowed to regenerate elsewhere across the site. The current focus on this specific area as opposed to the whole parcel and surrounding parcels makes it unlikely that existing restoration efforts will adequately return the site to its pre-contact conditions. Instead, the health and vitality of the oak woodland as a contemporary, living resource should be strategized as a part of broader conservation objectives rather than a singular preservation measure.

These conclusions about the effectiveness of the current project actions in no way diminish the labors of the Tribes or the Forest in attempting to manage Mvs-yee-se'-ne over the last 30 years. The no-action alternative would have offered no ecological or cultural benefits while the oak stand would have continued to be neglected. This proactive strategy, while restricted in its successes, provided a useful model from which to strengthen the ongoing collaborative approach and to engage in the process of learning. Stankey et al. describe the concept of learning as central to adaptive management practice, functioning as both a driver and a product (Stankey et al. 2005:14). Active adaptive management exists within a world of risk and uncertainty that relies on opportunities such as those present at Mvs-yee-se'-ne to strategize as a means of future planning and action.

Conclusions made here should also be considered preliminary evaluations. The opinions of this author may not be the same as other stakeholders, especially those with long-term vested interests. Adaptive management is a sociopolitical practice, opening the door for diverse interests and perspectives to be legitimized and addressed, rather than attempting to create a single perspective or consensus of values (Stankey et al 2005:40). Returning to Boedhihartono and Sayer (2017), the computerized image classification and mapping results presented in this thesis can be used to visualize a desirable scenario for returning the landscape at Mvs-yee-se'-ne to its probable original condition, particularly around the grassland. It is with the sincerest hope that this information will be useful to

Tribal and agency partners who continue to look for the best ways to co-manage this landscape presently and into the future.

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APPENDIX A. TIMELINE OF BURNING ACTIVITIES

The following dates were provided by Sheila Balent, Fuels Planner for the Six Rivers Smith River National Recreation Area:

1995: Handpiling and burning around perimeter of oak stand

1996: Fire reintroduced through ten acres of Oregon oak stand

2001: 15 acre maintenance burn

2008: 15 acre maintenance burn

2010: 5 acres outside the Oregon white oak stand is burned

2011: 15 acres maintenance burn in the fall

2014: 4.5 acres outside the Oregon white oak stand is burned.

2016: Planned maintenance burn – not performed

2018: 15 acres maintenance burn in the fall

APPENDIX B. LINEAR REGRESSION STATISTICS CALCULATED IN EXCEL

Table 2a-d. Regression statistics for yellow pine where core reached pith or pith was estimated within 10 years.

Regression Statistics	*Value*
Multiple R	0.588110103
R Square	0.345873493
Adjusted R Square	0.280460842
Standard Error	12.92247756
Observations	12

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	882.9723518	882.9723518	5.287562715	0.044294239
Residual	10	1669.904263	166.9904263		
Total	11	2552.876615			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1063.297562	449.7407789	2.364245388	0.03966488
X Variable 1	-0.525050085	0.228335252	-2.299470094	0.044294239

	Lower 95%	*Upper 95%*
Intercept	61.21265949	2065.382465
X Variable 1	-1.033812732	-0.016287437

Table 3a-d. Regression statistics for incense cedar where core reached pith or pith was estimated within 10 years.

Regression Statistic	*Value*
Multiple R	0.668755527
R Square	0.447233955
Adjusted R Square	0.39195735
Standard Error	10.75931904
Observations	12

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	936.6190386	936.6190386	8.090836232	0.017415325
Residual	10	1157.629461	115.7629461		
Total	11	2094.2485			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1048.855639	360.4849121	2.909568762	0.015576225
X Variable 1	-0.521425337	0.183313912	-2.844439529	0.017415325

	Lower 95%	*Upper 95%*
Intercept	245.6452013	1852.066078
X Variable 1	-0.929874186	-0.112976488

Table 4a-d. Regression statistics for Douglas-fir where core reached pith or pith was estimated within 10 years.

Regression Statistic	*Value*
Multiple R	0.005547055
R Square	3.07698E-05
Adjusted R Square	-0.124965384
Standard Error	16.0600064
Observations	10

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.063492101	0.063492101	0.000246166	0.987866191
Residual	8	2063.390445	257.9238057		
Total	9	2063.453938			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	22.99157947	755.7507171	0.030422174	0.976475633
X Variable 1	0.006037896	0.384832291	0.015689682	0.987866191

	Lower 95%	*Upper 95%*
Intercept	-1719.772699	1765.755858
X Variable 1	-0.881386958	0.89346275

Table 5a-d. Regression statistics for white oak where core reached pith or pith was estimated within 10 years.

Regression Statistic	*Value*
Multiple R	0.912420681
R Square	0.832511499
Adjusted R Square	0.799013799
Standard Error	6.796708248
Observations	7

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1148.080935	1148.080935	24.85279566	0.004156917
Residual	5	230.976215	46.19524301		
Total	6	1379.05715			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1355.403359	264.3905391	5.126519894	0.003686853
X Variable 1	-0.708543853	0.142127825	-4.985257832	0.004156917

	Lower 95%	*Upper 95%*
Intercept	1885.208816	1927.595003
X Variable 1	-1.76810562	-0.72825361

APPENDIX C. AERIAL PHOTOGRAPHS OMITTED FROM TEXT

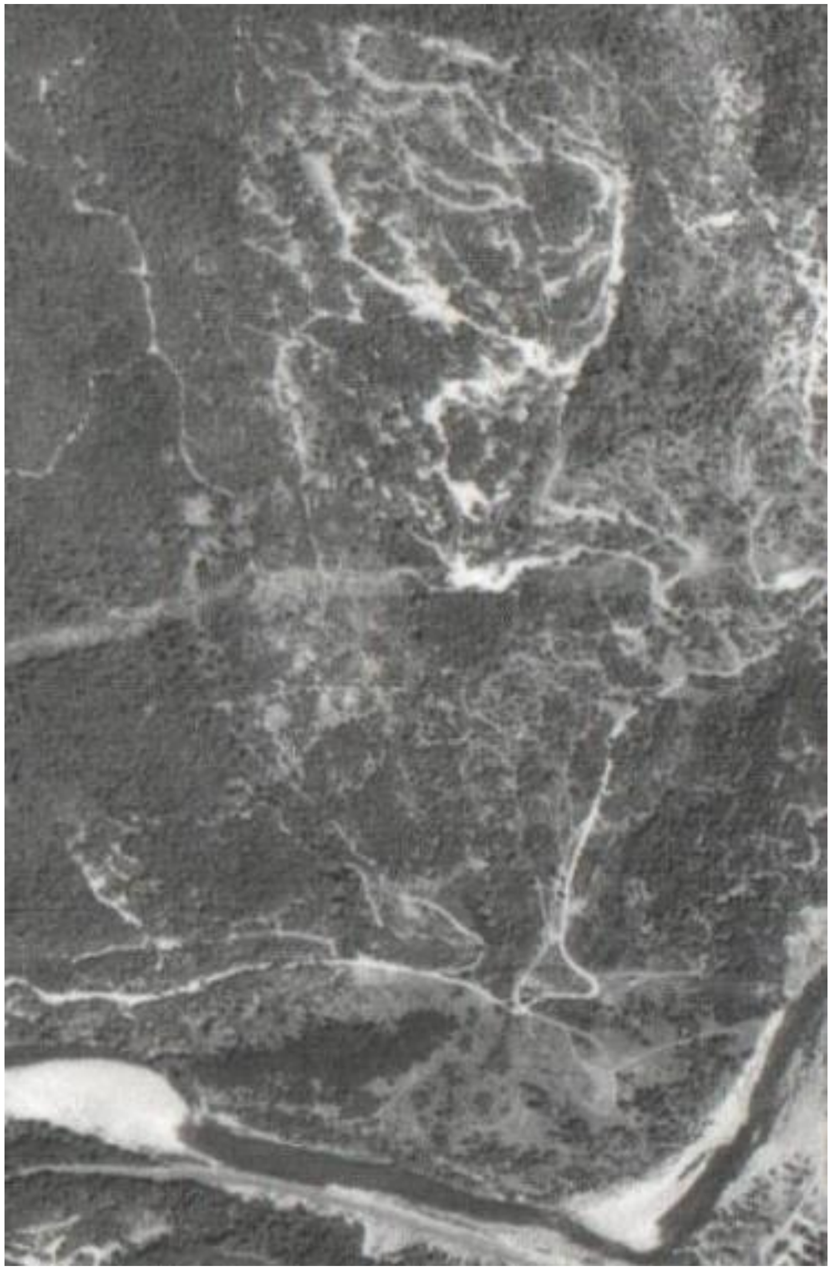

Figure 16. Detail, aerial photograph, unknown flightline, June 12, 1968.

Figure 17. Detail, aerial photograph EVZ-1-98, July 7, 1970.