Effects of Thinning and Prescribed Fire in the Goosenest Adaptive Management Area in Northeastern California

Martin W. Ritchie[1]

ABSTRACT.—The Goosenest Adaptive Management Area was established in 1994 on the Klamath National Forest with the intent of evaluating late-successional forest characteristics. A large-scale experiment was established in the late 1990s to evaluate a range of management strategies. Treatments include combinations of mechanical thinning and prescribed fire. Observations 6 and 14 years after establishment were analyzed to evaluate effects on large tree component of the stand as well as species distribution and coarse woody debris. Thinning treatments accelerated growth of retained trees and modified proportion of ponderosa pine due to two factors: high levels of ponderosa pine mortality in control treatments, and the effects of group-selection plantations. Two applications of prescribed fire had little effect on stand structure and species distribution but did influence surface fuels >3 inches in size. Current rates of growth suggest that longevity of these treatments is on the order of 20 years.

INTRODUCTION

In response to difficulties encountered managing forests of the Pacific Northwest, a large scale assessment effort was conducted in the early 1990s by the Forest Ecosystem Management Assessment Team (FEMAT) with a focus on lands managed by the USDA Forest Service and U.S. Bureau of Land Management (USDA and USDI 1993). The resulting Record of Decision for the Northwest Forest Plan (USDA and USDI 1994) relied on adaptive management as one key facet of a comprehensive plan for this region. A network of 10 adaptive management areas (AMA) in forests within the range of the northern spotted owl (*Strix occidentalis caurina*) were established with the intent of providing an opportunity to learn how to improve ecosystem management in forests managed by the Forest Service and the Bureau of Land Management. Among these is the 173,000-acre Goosenest Adaptive Management Area (GAMA) on the Klamath National Forest in northeastern California. The stated emphasis for GAMA was: *"Development of ecosystem management approaches, including the use of prescribed burning and other silvicultural techniques, for management of pine forests, including objectives related to forest health, production and maintenance of late-successional forest and riparian habitat and commercial timber production"* (USDA and USDI 1994, page D-14).

A study was implemented with a range of treatment intensities to address the overall goals of the AMA designation in the late 1990s. The purpose of this paper is to evaluate the results of this study as they relate to conifer species distribution, recruitment of large trees, and surface fuel accumulation 14 years after treatment.

[1] Research Forester, USDA Forest Service, Pacific Southwest Research Station, 3644 Avtech Parkway, Redding, CA 96002. To contact, call 530-226-2551 or email at martin.ritchie@usda.gov.

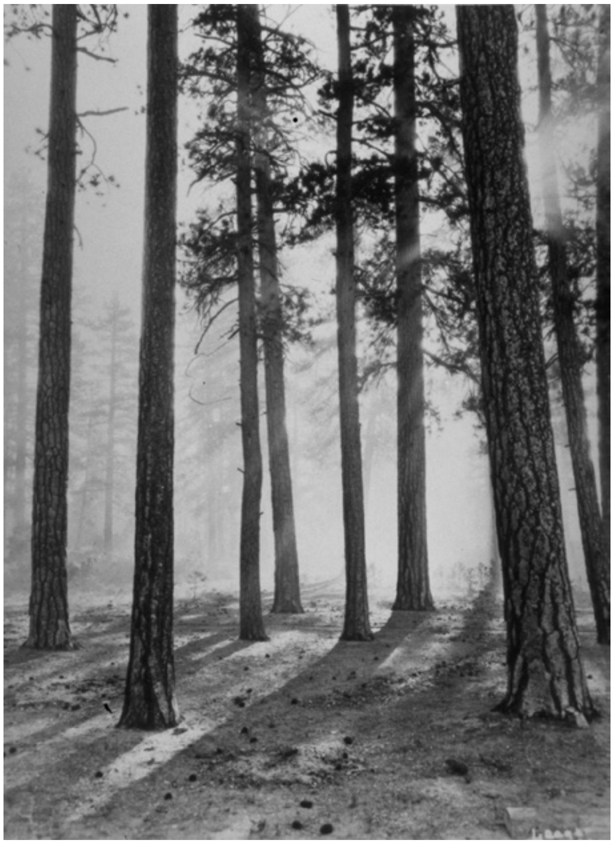

Figure 1. —Photo of stand in the Goosenest region ca. 1920 prior to harvest. Photo by USDA Forest Service.

STUDY AREA

Prior to European settlement, conditions for this region of northern California were influenced by the presence of frequent low-intensity wildfire (Skinner and Taylor 2006). This tended to produce open stands (Fig. 1) with many large diameter ponderosa pine (*Pinus ponderosa*) trees (Laudenslayer and Darr 1990). The forests of GAMA were harvested by Long-Bell Lumber Company in the 1920s and 1930s, removing much of the ponderosa pine while leaving behind sub-merchantable and cull pine and other less favorable trees, primarily white fir (*Abies concolor*). The Forest Service subsequently acquired these cut-over lands.

In the decades since first harvest, these formerly pine-dominated forests regenerated with stands heavy to white fir—about 60 percent by basal area. The next most common species is ponderosa pine. Other species encountered occasionally throughout the study area are incense-cedar (*Calocedrus decurrens*) and, at higher elevations, red fir (*Abies magnifica*), sugar pine (*Pinus lambertiana*), and lodgepole pine (*P. contorta*). But in general, these stands can be considered a two-species mix, white fir and ponderosa pine, with a minor component of other conifers.

By the time Northwest Forest Plan (USDA and USDI 1994) was enacted, stand conditions could be described as overstocked second growth with a median relative density of 0.70 (range 0.5 to1.1) with an assumed limiting stand density index[2] (SDI) for ponderosa pine of 400 (Ritchie 2005). Limiting SDI is an average upper bound for this metric; published research on

[2] Stand Density Index (SDI) – An expression of relative stand density based on the predictable relationship between average tree size and trees per unit area in dense stands. This relationship, independent of both stand age and site quality, provides an excellent basis from which to develop an understanding of the competitive interactions between individuals in a population.

this maximum ranges from 365 in the presence of *Dendroctonus* bark beetles (Oliver 1995) to 450 (Long and Shaw 2005). Quadratic mean diameters ranged from 9.7 to 16.2 inches (for trees greater than 4.0 inches diameter at breast height (d.b.h.; measured 4.5 ft above ground). Large trees were observed to be sparse or non-existent and the diameter distribution exhibited large numbers of small trees (Ritchie 2005).

With the establishment of the AMAs, several management issues were defined for GAMA. Among these were (1) declining forest health due to high stand density and fir encroachment, (2) potential for extreme fire behavior due to high mortality and fuels accumulations and a past history of fire exclusion, (3) lack of late-successional conditions due to past harvest activity, and (4) a need to achieve sale quantity goals in the forest plan (USDA Forest Service, Klamath National Forest 1996).

In 1995, an interdisciplinary team of researchers from the Pacific Southwest Research Station and Humboldt State University, working with personnel from the Klamath National Forest, began designing a study at GAMA to investigate the effects of mechanical thinning and prescribed fire on an array of late-successional forest attributes related to late-successional forests (Oliver 2001, Ritchie 2005). Among these are: conifer species distribution, recruitment and retention of large diameter trees, and surface fuel levels. The research team considered potential for research was best in an area of mid-elevation with a potential for developing a commercial timber harvest. The study area selected is near Tenant, CA (41.563°, -121.858°) with elevation ranging from 4800 to 5800 ft. Slopes are gentle, generally <15 percent, with a northeasterly aspect.

METHODS

In order to foster evaluation across a number of disciplines, the team elected to implement large-scale treatments, 100 acres each plus a buffer. The buffer target was ~100 m but occasionally was less when other features like roads were limiting. A 328 ft (100 m) grid of sample points were surveyed, with acceptable error of 6 inches, into each 100-acre treatment unit with each grid point having a Universal Transverse Mercator (UTM) reference stamped on the monument. Cross-disciplinary data to be collected in the study could thus be spatially referenced. Treatment unit boundaries and grid points were established in 1995 and 1996 (Fig. 2). NEPA analysis and presale work was conducted in 1997.

Experimental Treatments

The research team developed a completely randomized design of four treatments including a control, with all treatments replicated five times: 20 total treatment units. The treatments were described in detail by Ritchie (2005) and are summarized here.

Treatment 1: Control

The Control treatment dictated that no active management (including salvage, sanitation, or fuelwood cutting) would take place within the treatment unit boundary. This is a treatment consistent with a passive management strategy allowing stand development to be dictated by current conditions and future disturbance events. Since this is a completely randomized design, the expectation is that the Control treatments should be consistent with the pretreatment conditions of the other treatments and this appears to be the case. For example, tests of pretreatment estimates of trees per acre and quadratic mean diameter were found to be consistent across treatments.

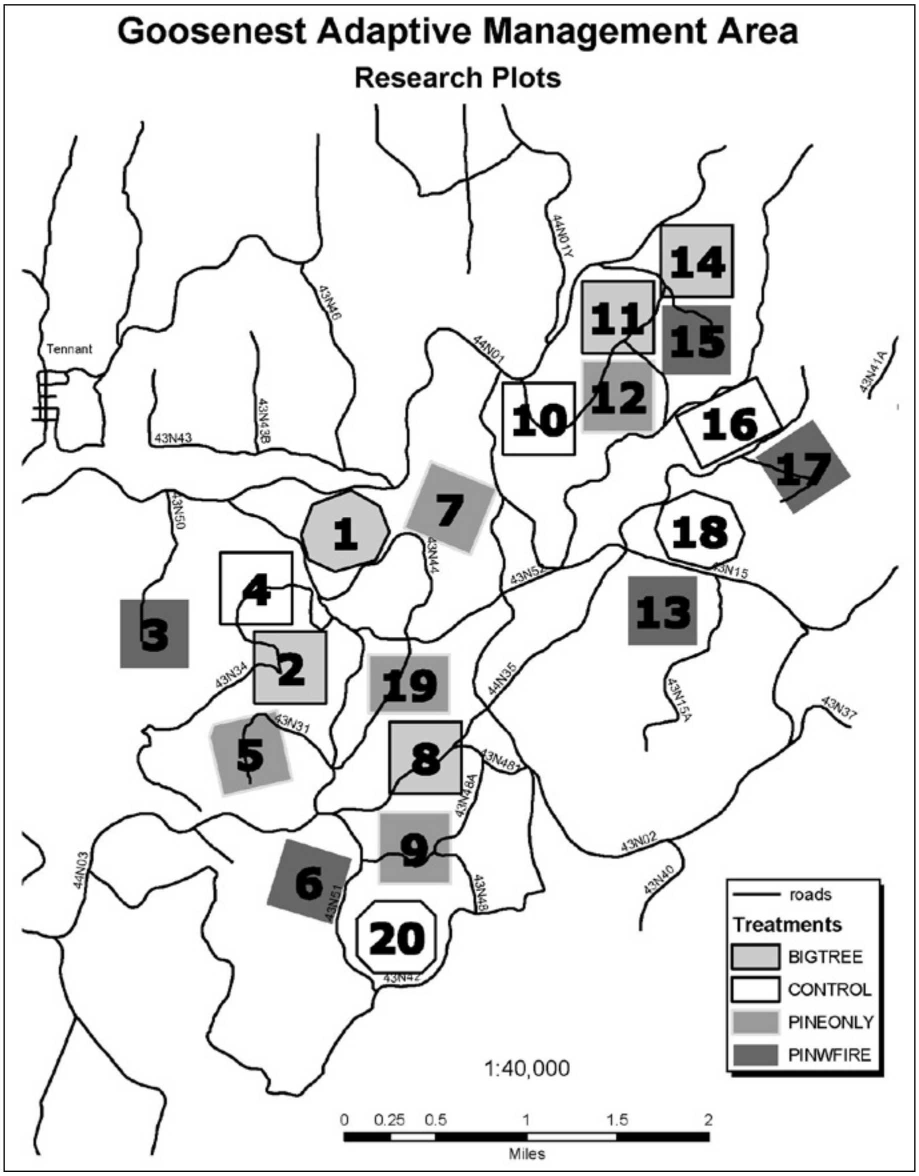

Figure 2.—Goosenest Adaptive Management Area treatment map. In the map legend, BIGTREE = Large Tree Emphasis treatment; PINE ONLY = Pine Emphasis treatment; PINWFIRE = Pine Emphasis with Fire treatment.

Treatment 2: Large Tree Emphasis

The Large Tree Emphasis treatment called for a thin from below with 18 to 25 foot spacing for dominant and codominant trees with no species preference. Whole-tree harvest was employed to reduce surface fuels. After harvest, all remaining trees <4.0 inches in d.b.h. were hand-felled with buck, lop, and scatter of tops and limbs. Treatment 2 should produce accelerated growth rate for trees and reduce tree mortality rates, as well as lower fire hazard due to reduced surface and ladder fuels. This treatment is similar in many respects to fuel reduction prescriptions commonly implemented throughout the Forest Service Region 5 (California) in recent years.

Treatment 3: Pine Emphasis

The Pine Emphasis treatment called for a thin-from-below process with a D+5 rule, subject to a retention guide for all dominant and codominant ponderosa pine >12-inch d.b.h., retention of all sugar pine and all incense-cedar >10-inch d.b.h.. The D+5 rule called for spacing (in feet), around retention trees as equal to d.b.h. + 5 so that a tree with a diameter of 16 inches would have a minimum radial release of 21 feet. After harvest, all trees <4.0 inches d.b.h. were hand-felled with buck, lop, and scatter of tops and limbs. In addition, because pine will not regenerate naturally under cover of fir, 15 percent of each Pine Emphasis area was subjected to group selection harvest with openings from 0.5–3.5 acre. Site preparation consisted of ripping with a winged subsoiler. Openings were then planted at 11-foot spacing with 2-0 bare root ponderosa pine seedlings between 2000 and 2002. In addition to increased growth and survival as well as reduced fire risk, this treatment should also produce the benefit of an increase the proportion of ponderosa pine and increase forest structural heterogeneity by developing a second age cohort.

Treatment 4: Pine Emphasis with Fire

The Pine Emphasis with Fire treatment is the same as Treatment 3, with the addition of the repeated application of prescribed fire. In addition to the anticipated benefits of Treatment 3, the presence of fire should further reduce surface and ladder fuels, increase crown base height, reduce the density of natural regeneration, and may also contribute to an increase in structural heterogeneity. Prescribed fire was applied in the fall of 2001 and then again 2010. During the first application of prescribed fire, the subsoil treatment effectively precluded fire damage to seedlings due to the lack of surface fuels. During the second prescribed fire entry, crews were directed to avoid entering the openings and generally the fuels were not sufficient to carry fire through the plantations.

Because of the scale of the project, mechanical treatments were implemented over a period of 3 years (1998-2000). Harvests removed a total of 68,000 green tons of biomass and 18 million board feet (MMBF) of saw logs for sale revenue of $5.5 million. The first post-treatment observations were made in 2002. The most recent observations were conducted in 2005 and again in 2013; these last two observations are evaluated in this paper.

Standing Trees

The sampling protocol for trees and snags employed a nested circular plot design centered on grid points at a spacing of 464 feet (every other grid point). Trees and snags >11.5 inches d.b.h. were measured on a 0.2-acre plot. Trees and snags >4.5 inches and ≤11.5 inches d.b.h. were measured on a 0.05-acre plot. All live seedlings (trees <4.5 feet in height) and saplings (trees with d.b.h. 0.0 to 4.5 inches) were tallied by species on a 0.01-acre plot.

In 2005, a total of 5,077 live trees were sampled along with 552 snags, 349 of which were in Control treatment areas. In 2013 a total of 5,310 live trees were sampled along with 551 snags, 351 of which were in Control treatment areas. There were a total of 360 plot measurements in both 2005 and 2013. The increase in number of sampled live trees is due to ingrowth.

Because one of the key questions is the longevity of treatments, stand density index (SDI) (Reineke 1933) was used to evaluate the trajectory of stands and the need for retreatment assuming a SDI upper limit of 400 with a management zone between 120 and 220 (relative density 0.30 to 0.55).

To evaluate change in the large tree component of these stands, we calculated the net change in number of large (>24 inch d.b.h.) trees. This analysis was augmented by fitting a peaking growth function for squared diameter increment on 4,566 repeat observations of ponderosa pine and fir trees >4.5 inches:

$$ln(bagrow) = (\beta_{00} + \beta_{01}I_s + \beta_{02}I_t) + (\beta_{10} + \beta_{11}I_s + \beta_{12}I_t)ln(DBH) + (\beta_{2i} + \beta_{2i}I_s)DBH^2 + \varepsilon$$

Where,

$ln(bagrow)$= natural log of basal area increment (square inches),

β_{ij} = parameters to be estimated,

I_s = Indicator for species, 1 for pine, 0 otherwise,

I_t = Indicator treatment, 1 for treated, 0 for control,

ε = model error term

This function is similar in form to that originally employed in the Forest Vegetation Simulator (Cole and Stage 1972, Stage 1973).

The contribution of ponderosa pine was calculated by basal area of pine expressed as a percentage of the total basal area.

Woody Debris

A 328 ft line-intercept transect was centered on each measured grid point (approximately 18 per treatment unit). Woody debris were sampled following the protocol of Brown (1971). Fuel pieces between 1 and 3 inches in diameter were sampled in a 12-foot section randomly located along the transect. Biomass of woody surface fuels >3 inches in diameter was calculated and compared among treatments. Sampled wood was characterized by decay class as an ordinal variable. Decay class 1 is primarily sound wood with little evidence of decay. Decay class 2 is wood with significant evidence of decay but still structurally sound. Decay class 3 is wood which has lost all structural integrity.

RESULTS

The focus of this analysis is the 8-year period (2005 to 2013). For convenience, these will be referred to as year 6 and year 14 since treatment establishment. Analysis of variance for a balanced design with five replicates of four treatments are presented.

Contrast in stand structure across treatments at year 14 shows the large differences in density among smaller trees, with much lower density among trees less than about 18 inches d.b.h. and a higher proportion of ponderosa pine, particularly in the pine emphasis treatments. Also evident is the early stages of ingrowth from the planted group selection openings in the Pine Emphasis and Pine Emphasis with Fire treatments (Fig. 3). At this age, the planted seedlings were just beginning to cross the 3.5-inch threshold for our larger plot samples. In the 2005 measurement, many of the planted trees were still below breast height (<4.5 inches in height).

SDI at age 14 shows that some treated stands are at or above the upper limit of the management zone (Fig. 4). Untreated stands remain clustered near the assumed maximum of 400 for pine. Ponderosa pine at SDI above the upper management zone of 220 are at high risk of bark beetle-induced mortality (Fettig 2012, Oliver 1995).

One of the objectives of the research was to evaluate the recruitment of large trees over time. An evaluation of the number of trees >24 inches d.b.h. reveals no difference among treatments in this metric (P=0.42) in the growth period between year 6 and 14 (Fig. 5), although there is evidence of a slight increase in the treated units.

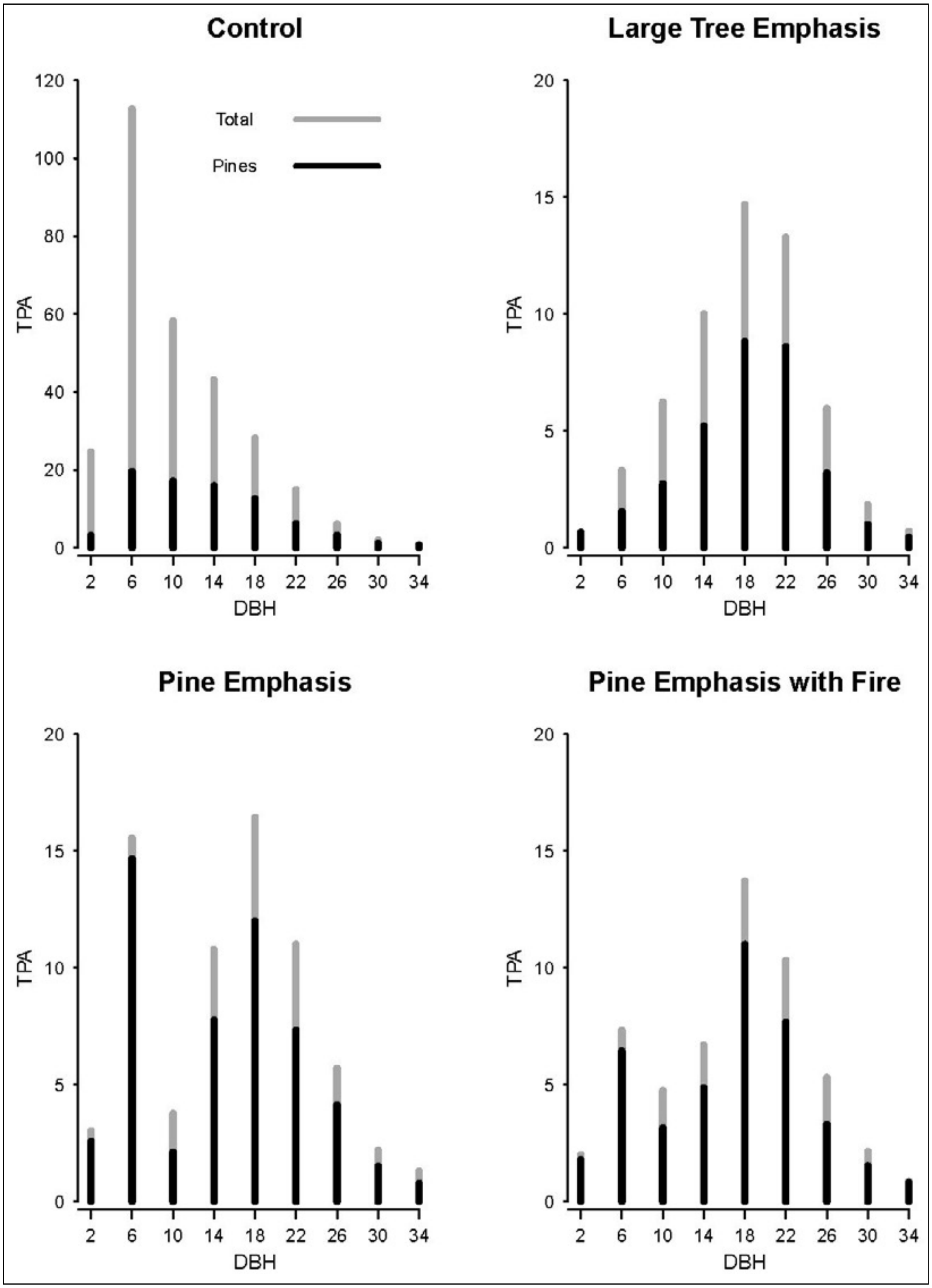

Figure 3. —Composite diameter (DBH) and density (TPA) distributions by treatment in 2013, approximately 14 years since treatment installation. DBH = diameter at breast height, in inches, and TPA = trees per acre. Pine group (darker portion of each bar) includes all pines and incense-cedar.

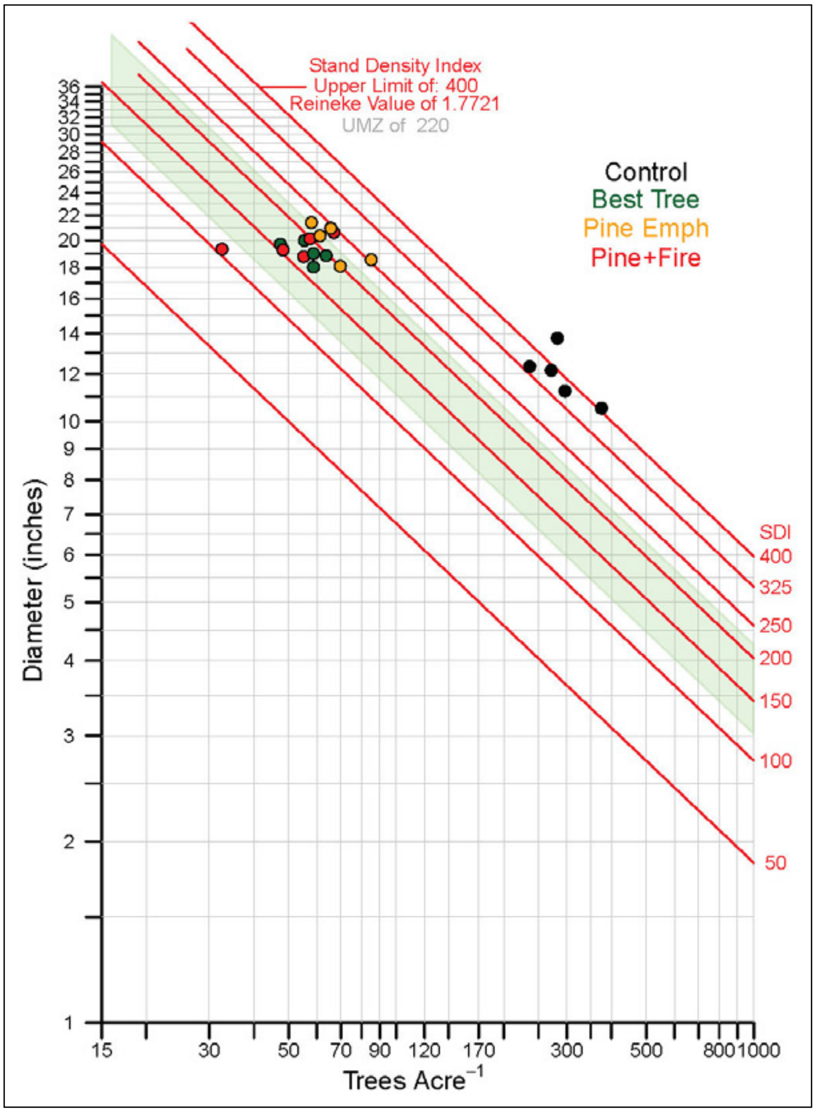

Figure 4. — Density management diagram (assume limiting SDI=400) with treatment plots at approximately 14 years post-treatment in the Goosenest Adaptive Management Area. UMZ = upper management zone. Green shaded area indicates the management zone between SDI=120 and 220.

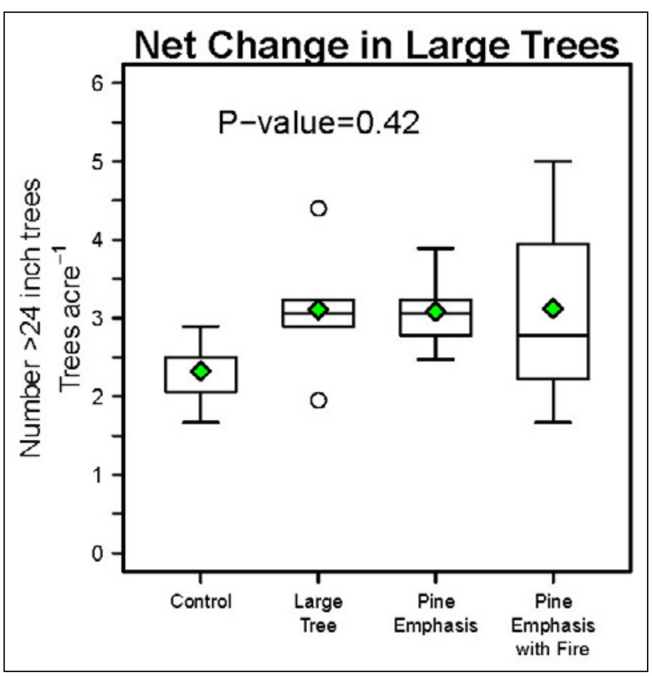

Figure 5. — The change in the density (trees per acre) of large trees (>24 inches d.b.h.) by treatment in the period between 6 and 14 years post-treatment. There is no apparent difference in number of large trees in any of the treatment areas.

Table 1.—Parameter estimates for 8-year basal area increment model for ponderosa pine and fir trees at the Goosenest Adaptive Management Area , where Y=ln(bagrow), and bagrow is individual tree basal area growth in square inches. Note the model is parameterized such that indicator variables are added for pine parameter differential and treatment parameter differential and intercept estimate is not corrected for log bias.

Term	Parameter	Estimate	S.E.	P value
Intercept	β_{00}	-1.34853	0.0805	<0.0001
	β_{01} (species=pine)	-0.81656	0.172	<0.0001
	β_{02} (treated)	2.17540	0.143	<0.0001
ln(DBH)	β_{10}	1.84531	0.0401	<0.0001
	β_{11} (species=pine)	0.15325	0.0757	0.0430
	β_{12} (treated)	-0.58110	0.0510	<0.0001
DBH^2	β_{20}	-0.0008926	0.000111	<0.0001
	β_{21} (species=pine)	0.00005797	0.000149	0.6974
RMSE		0.516		

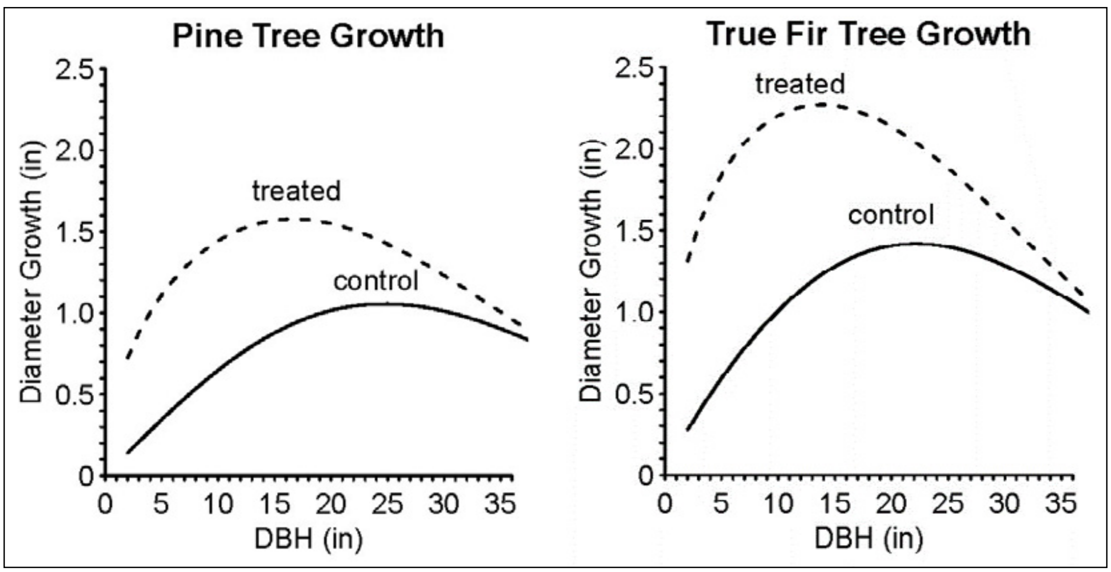

Figure 6. —Tree diameter growth model for ponderosa pine (A) and true fir (B) for the period 6 to 14 years post-treatment, at the Goosenest Adaptive Management Area. The two lines in each graph contrast the five control plots with the treated units.

The fitted individual-tree growth model reveals that fir trees are growing faster than pine trees at GAMA (Table 1), and that treated units had greater growth than controls (Fig. 6). Eight-year increment for white fir peaked at 2.3 inches (0.29 inches yr^{-1}) in treated stands versus 1.4 inches (0.18 inches yr^{-1}) in untreated stands. In similar fashion, pine increment in treated areas peaked at about 1.6 inches (0.20 inches yr^{-1}) while untreated pine peaked at approximately 1.0 inch (0.13 inches yr^{-1}). When a term was added for the effect of fire on the intercept and log of diameter, the influence was minimal (P=0.48 and 0.42, respectively).

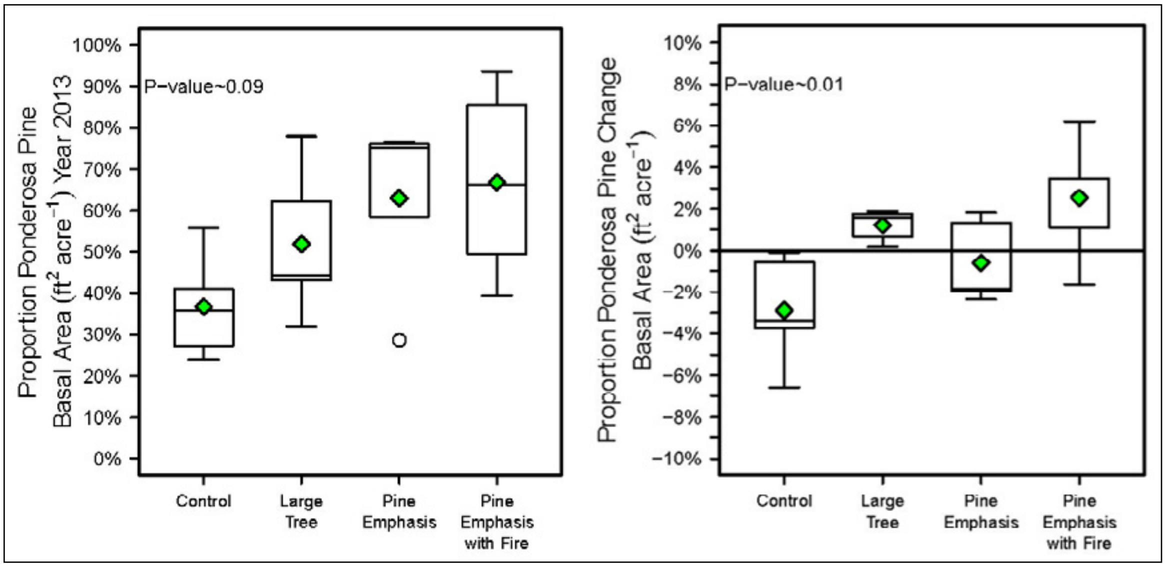

Figure 7. —Proportion of ponderosa pine (A) and the change in ponderosa pine proportion (B) for the period 6 to 14 years post-treatment, Goosenest Adaptive Management Area.

The most recent observation shows a marginal difference (P=0.09) in proportion of ponderosa pine by basal area. However there is strong evidence of a treatment effect on the periodic change in species proportion with the control units appearing to lose proportion of pine over the previous 8 years (Fig. 7). This is due primarily to accelerated rates of pine mortality in the controls. As shown in Figure 4, the controls are at or near the limiting SDI for pine and these units lost, on average about 28 trees acre^{-1} in 8 years while the Large Tree Emphasis treatment held steady. In contrast, the Pine Emphasis and Pine Emphasis with Fire treatments both gained trees (19 acre^{-1} for Pine Emphasis and 12 acre^{-1} for Pine Emphasis with Fire) and this gain is in evidence in Figure 3; it appears to be primarily in the smaller diameter classes, which at this time have little in terms of basal area but high numbers of stems in the plantations. The group selection plantations are beginning to be picked up by our sampling methods more efficiently as trees cross the 3.5-inch threshold and have a higher probability of sampling.

Analysis of variance of coarse woody debris by decay class (Fig. 8) demonstrates there is little influence of any treatments on sound wood (decay class 1) at GAMA (P=0.42). However there is an impact of our treatments on wood with a more advanced state of decay. Thus prescribed fire was effective in reducing some fuels in the short term, but it may take repeated entries to have a more profound effect on accumulations of sound wood. There is also some evidence of a reduction in decay class 3 in Pine Emphasis Treatments, where prescribed fire was not implemented.

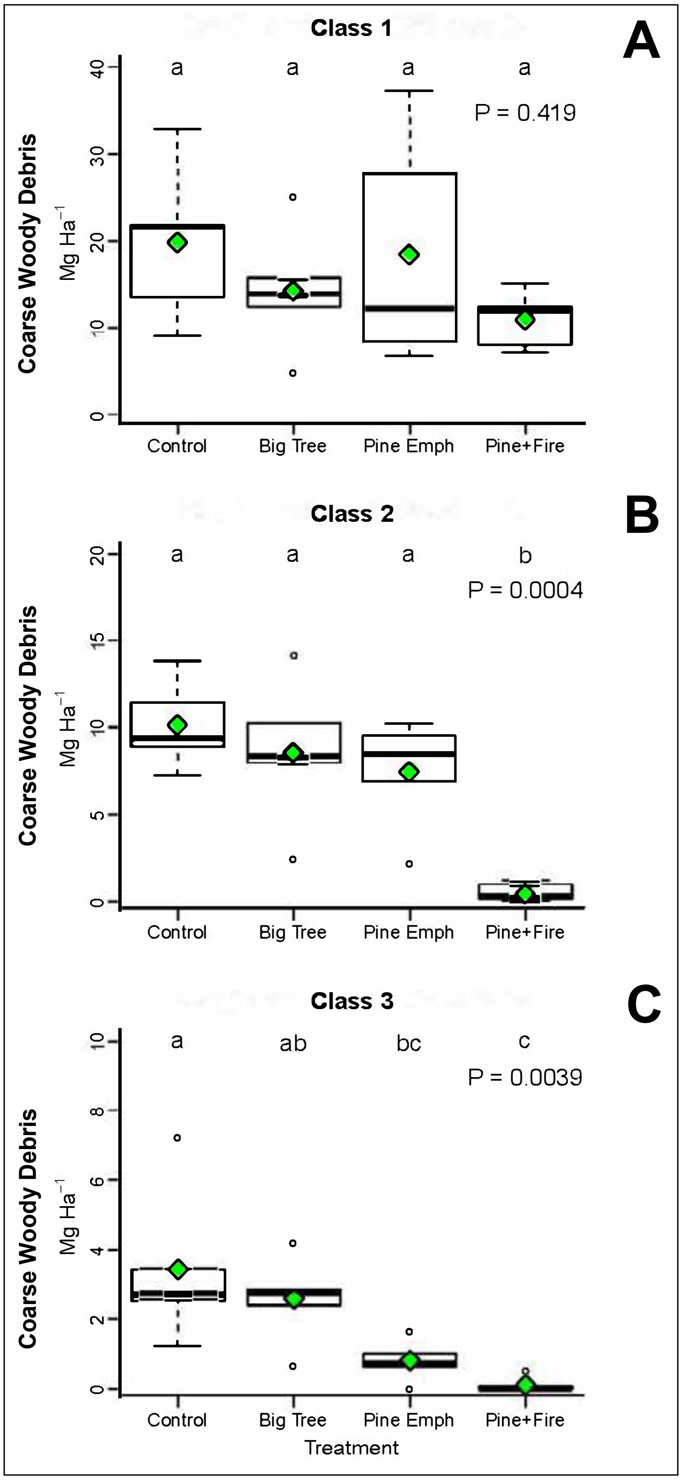

Figure 8. —Coarse woody debris (>3 inch) by decay classes 1 (A), 2 (B), and 3 (C), 14 years post-treatment, Goosenest Adaptive Management Area. Different letters that appear at the top of the graph, above the bars, indicate significant differences.

DISCUSSION

The evaluation of the stands in the Goosenest AMA research project 14 years after treatment shows some evidence of development of the late-successional attributes. Trees have accelerated growth rates and ponderosa pine mortality has been greatly reduced in treated areas. Also, introduction of prescribed fire has reduced surface fuels, which should aid in fire resilience. Despite the increase in growth rates, the recruitment of large trees (>24 inches d.b.h.) has not yet occurred. Developing a greater number of large trees is a long-term problem in second growth stands, there is no quick fix. Given the age of the stands (about 80 years old) this is not all that surprising. Given the diameter distribution and current growth rates, it is likely that we will see evidence of an increase in number of trees >24 inches 20–25 years post-treatment. The growth advantage of white fir over pine is one other factor contributing to the ability of fir to dominate these sites. The growth rate difference between species suggests a competitive advantage for fir at this site. To the degree that prescribed fire can disproportionately remove white fir regeneration, it will provide a long-term advantage for ponderosa pine.

The Pine Emphasis treatments, both with and without fire, have influenced the species distribution and this will continue due to the rapid development of the planted group selection openings. Advanced rates of pine mortality continue unabated in the controls due to the elevated density in these units which favors the continued dominance of fir. In contrast to elevated mortality in ponderosa pine, fir in the control units is surviving well. The control units have an SDI of about 400, a comfortable density for fir, which has a limiting density of about 800. But this is well above the zone of imminent mortality for ponderosa pine.

Unfortunately our sampling methods in the early stages of this study have a fixed-plot spacing of one plot every 5 acres and this is inadequate to really capture what is going on in the group selection units as most of the groups are not sampled. We will need to augment sampling by stratifying the plantations and sampling more intensively in future measurement cycles. The sector sampling method of Iles and Smith (2006) seems like a promising approach to this problem. Sector sampling is an innovative approach to sampling small areas that is free from the liability of edge-effect sampling bias. We have initiated sector sampling in the 2019 measurement of the group selection units. We hope this allows for a more detailed and precise description of the changes in structure over time.

At the time of the most recent observations, there was little evidence of a prescribed fire effect on either rates of growth or species distribution of living trees. One area where the effects of prescribed fire can be seen is on the distribution of coarse woody debris. Prescribed fire has reduced the amount of surface fuels, particularly in the fuel with a more advanced state of decay. Stage 3 material is essentially at zero in areas with prescribed fire. This is consistent with the findings of other studies (e.g., Uzoh and Skinner 2009). Since much of the decay class 1 wood dates to a recent windthrow event, this material is at this time more impervious to the effects of prescribed fire because there hasn't been enough time for it to break down. With repeated applications of prescribed fire, we would expect even more effective fuel reduction in the future as much of this material reaches a more advanced state of decay. Anecdotally, it also appears that prescribed fire has had little impact on development of the shrubs, and this is likely due to the time of year that burning is conducted and the prescriptions that call for a cool burn. We might obtain a better result with a more consumptive prescription.

The elevated rates of pine mortality in the untreated units along with the superior observed growth of fir in all treatments underscores the challenge in managing for pine at GAMA. Historically ponderosa pine was able to overcome these disadvantages because of the influence of fire; a fire regime with frequent low to mid severity burns discriminated against fir. In the absence of this natural disturbance the ponderosa pine component will need assistance if managers wish to feature pine with the desired goal of creating stands with greater resilience to wildfire. Our current fire regime is one in which wildfire occurs more infrequently but with greater intensity. Prescribed fire may work well but it may be worth considering changing the prescriptions to allow for a hotter fire. This could produce a more effective reduction of fuels, fir regeneration, and the understory shrub component.

Our observed densities in the treated units 14 years after thinning suggest that we need to consider rethinning of these stands at the 20 year mark followed by a third prescribed fire application in the Pine Emphasis with Fire treatment. Given the current diameter distributions, we could consider a proportional thinning followed by another hand thinning of white fir saplings <4 inches d.b.h.. The Adaptive Management Area has approximately 111,000 acres of commercially viable timberland (USDA Forest Service, Klamath National Forest 1996). If this area were to be managed with a goal of achieving more fire resilient stands using treatments similar to those employed in this study with a 20 year re-entry schedule, it would require a management intensity of approximately 5,500 acres year^{-1} just to get these areas into a more resilient condition. If a similar volume recovery rate applied, this would produce 65 MMBF annually removed from the forests of the Goosenest Adaptive Management Area, just to maintain a resilient condition on these productive acres of the AMA.

A 20-year remeasurement of this study is underway in 2019 and this will help guide any decisions on future mechanical treatments and prescribed fire. Researchers hope to once again work with Klamath National Forest staff to develop prescriptions that will allow for the continuation of this study.

ACKNOWLEDGMENT

The author thanks current and former personnel of the Goosenest Ranger District for assistance and support over the 25 years of work at the Goosenest Adaptive Management Area.

LITERATURE CITED

Brown, J.K. 1971. **A planar intersect method for sampling fuel volume and surface area.** Forest Science. 17: 96-102.

Cole, D.M.; Stage, A.R. 1972. **Estimating future diameters of lodgepole pine trees.** Res. Pap. INT-131. Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Rage Experiment Station. 20 p. https://doi.org/10.2737/INT-GTR-131.

Fettig, C.J. 2012. **Forest health and bark beetles. Chapter 2.** In: North, M., ed. Managing Sierra Nevada forests. Gen. Tech. Rep. PSW-237. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 13-22. https://doi.org/10.2737/PSW-GTR-237.

Laudenslayer, W.F., Jr.; Darr, H.H. 1990. **Historical effects of logging on the forests of the Cascade and Sierra Nevada ranges in California.** Transactions of the Western Section of the Wildlife Society. 26: 12-23.

Long, J.N.; Shaw, J.D. 2005. **A density management diagram for even-aged ponderosa pine stands.** Western Journal of Applied Forestry. 20(4): 205-215.

Oliver, W.W. 1995. **Is self-thinning in ponderosa pine ruled by Dendroctonus bark beetles?** In: Eskew, L.G., comp. Forest health through silviculture: proceedings of the 1995 National Silviculture Workshop; 1995 May 8-11; Mescalero, NM. Gen. Tech. Rep. RM-267. Fort Collins CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 213-218.

Oliver, W.W. 2001. **Can we create and sustain late successional attributes in interior ponderosa pine stands? Large-scale ecological research studies in northeastern California.** In: Vance, R.; Edminster, C.B.; Covington, W.W.; Blake, J.A, comps. Ponderosa pine ecosystems restoration and conservation: Steps toward stewardship. Proc. RMRS-P-22. 2000 April 25-27; Flagstaff, AZ. Ogden UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 99-103.

Reineke, L.H. 1933. **Perfecting a stand density index for even-aged forests.** Journal of Agricultural Research. 46: 627-638.

Ritchie, M.W. 2005. **Ecological research at the Goosenest Adaptive Management Area in northeastern California.** Gen. Tech. Rep. PSW-192. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 120 p. https://doi.org/10.2737/PSW-GTR-192 .

Skinner, C.N.; Taylor, A.H. 2006. **Southern Cascades bioregion.** In: Sugihara, N.G.; van Wagtendonk, J.W.; Fites-Kaufmann, J. [et al.], eds. Fire in California's ecosystems. Berkeley, CA: University of California Press. 568 p.

Iles, K.; Smith, N.J. 2006. **A new type of sample plot that is particularly useful for sampling small clusters of objects.** Forest Science. 52:148-154.

Stage, A.R. 1973 **Prognosis model for stand development.** Res. Pap. INT-137. Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 32 p.

USDA Forest Service, Klamath National Forest. 1996. **Goosenest Adaptive Management Area Klamath National Forest Goosenest Ranger District, ecosystem analysis.** Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 187 p. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5403301.pdf (accessed Feb. 19, 2020).

U.S. Department of Agriculture [USDA] and U.S. Department of Interior [USDI]. 1993. **Forest ecosystem management: an ecological, economic, and social assessment.** Report of the Forest Ecosystem Management Assessment Team. Washington, DC: U.S. Department of Agriculture, Forest Service and U.S. Department of Interior, Bureau of Land Management, among other agencies. 1032 p. https://www.blm.gov/or/plans/nwfpnepa/FEMAT-1993/1993_%20FEMAT_Report.pdf (accessed Feb. 19, 2020).

U.S. Department of Agriculture [USDA] and U.S. Department of Interior [USDI]. 1994. **Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl.** Washington, DC: U.S. Department of Agriculture and U.S. Department of Interior. 74 p. https://www.fs.fed.us/r6/reo/nwfp/documents/reports/newroda.pdf (accessed Feb. 19, 2020).

Uzoh, F.C.C.; Skinner, C.N. 2009. **Effects of creating two forest structures and using prescribed fire on coarse woody debris in northeastern California, USA.** Fire Ecology. 5(2):1-13. https://doi.org/10.4996/fireecology.0502001.

CITATION: Ritchie, Martin W. 2020. Effects of thinning and prescribed fire in the Goosenest Adaptive Management Area in northeastern California. In: Pile, Lauren S.; Deal, Robert L.; Dey, Daniel C.; Gwaze, David; Kabrick, John M.; Palik, Brian J.; Schuler, Thomas M., comps. The 2019 National Silviculture Workshop: a focus on forest management-research partnerships. Gen. Tech. Rep. NRS-P-193. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station: 193-206. https://doi.org/10.2737/NRS-GTR-P-193-paper25