06/20/2018

Mr. Justin Thompson, District Fire Management Officer
Clifton Ranger District, Apache-Sitgreaves National Forest
397240 AZ 75, Duncan, AZ 85534

Submitted via email at: https://cara.ecosystemmanagement.org/Public/CommentInput?project=50358

ATTN: East Eagle/Mud Springs Project

Dear Mr. Thompson,

Thank you for the opportunity to provide scoping comment on the East Eagle/Mud Springs Fuels Project on the Clifton Ranger District of the Apache-Sitgreaves National Forest, Arizona. Please accept these comments from the Center for Biological Diversity (The Center). The project NOI was published on May 23, 2018 in the Copper Era newspaper. The 30-day comment period ends on June 21, 2018 making these comments timely. At the Center for Biological Diversity, we believe that the welfare of human beings is deeply linked to nature — to the existence in our world of a vast diversity of wild animals and plants. Because diversity has intrinsic value, and because its loss impoverishes society, we work to secure a future for all species, great and small, hovering on the brink of extinction. We do so through science, law and creative media, with a focus on protecting the lands, forests, waters and climate that species need to survive. The author, as Southwest Advocate for the Center, provides these comments on behalf of our 60,000+ members and 1.6 million activist-supporters nationwide who value wilderness, biodiversity, old growth forests, and the threatened and endangered species which occur on America's spectacular public lands and waters. In addition to the Centers members and supporters who are lucky enough to live within the southern portion of the Apache-Sitgreaves National Forest, many more frequently use and enjoy the spectacular landscapes of the Apache-Sitgreaves National Forest landscape for recreation, sustenance, nature study, and spiritual renewal. The author of these comments has visited and enjoyed the area for more than 20 years, including a frightful period where he was stranded in the Blue Range Primitive Area during the Wallow Fire while completing a Stand Exam project for the Apache-Sitgreaves National Forest. He obviously lived to tell the tale.

The Center considers the proposed action a potentially highly beneficial project insofar as restoration and fuels treatments in forests, meadows, woodlands, and riparian areas are informed by the best available science and are coordinated within a cohesive and unified strategic approach. The proposed action seems to imply that the focus on this analysis is on the use of fire, both planned and unplanned ignitions, to achieve restoration objectives. We strongly support this approach and are eager to work with the Apache-Sitgreaves National Forest to develop a project that can harness the restorative benefits of fire in a way that compliments a variety of forest management goals and protects communities and other values at risk while not compromising habitats for threatened, endangered and sensitive wildlife species. Mechanical thinning treatments should be prioritized for protection of the WUI and critical infrastructure, and otherwise utilized in a strategic and optimized manner in order to facilitate restoration of landscape scale wildland fire for resource benefit. Such an approach is consistent with the National Cohesive Wildfire Management Strategy, the Statewide Strategy for Restoring Arizona's Forests, and the best available science.

The signed Scoping Package that was emailed out on May 22 stated that "*A supplemental project information sheet is provided on the project webpage which includes additional details about the project including but not limited to: background information and existing and desired conditions; various project design features, mitigation measures and best management practices; and specific treatment details as related to the vegetation type*." Unfortunately, this sheet does not appear to have ever been posted on the project webpage provided in the scoping package. Therefore, we cannot provide meaningful comment on the specific items listed above and look forward to seeing them described in detail in a Draft Environmental Assessment and public comment period.

There is considerable uncertainty of the historic range of variability for dry and wet mixed conifer forests, and more so spruce-fir forests, so we expect the Forest Service to address this gap in the science with site-specific analysis of existing conditions and an assessment of how regionally derived management directives are appropriate to the East Eagle/Mud Springs Fuels Project landscape. Ponderosa pine forests, too, are not entirely well understood in regards to the natural range of variability and the applicability of regional direction to the project area. We are particularly interested in the Forest Service identifying how regionally-derived desired conditions are tailored to the unique Terrestrial Ecosystem Units of the project area. We suggest that Cooper's seminal forest reconstruction and study work[1] be reviewed for its relevance to the East Eagle/Mud Springs Fuels Project landscape (see attached, and discussion later in this letter).

The occurrence of several federally listed wildlife species and a number of Forest Service Sensitive species in the project area demands a heightened level of attention to the specific habitat needs of each species. The synchronization of restoration treatments with fine-filter habitat requirements should be a primary objective in this analysis and to that end species Recovery Plans and the latest literature should inform and guide project design where those are available. The regionally disproportionately high occurrence of riparian and aquatic species within the project area, particularly Eagle Creek, demands enhanced consideration of those habitats.

The proposed action sits squarely within the footprint of the 4FRI landscape, and was at one point in time under consideration for incorporation as a "Phase III" of 4FRI. The Center is supportive of the collaboratively developed and consensus based agreements that have been established in 4FRI, and ask that those project design features are incorporated into the East Eagle/Mud Springs Fuels Project from the onset. This includes management direction for "SPLYT" stands, mistletoe treatments, treatments within Mexican spotted owl goshawk habitat, the old and large tree retention strategy, and other 4FRI elements. Key documents are attached to this letter. The years of collaborative work within 4FRI provides proof of concept for a convenient template for the design of the proposed action that is applicable to the East Eagle/Mud Springs Fuels Project with little need for modification. The incorporation of the "key ingredients" that are at the core of the 4FRI restoration design and the broader objectives for collaborative restoration projects in general will facilitate analysis, project decision, and ultimately implementation.

[1] Cooper, C.F. 1960. Changes in vegetation, structure and growth of southwestern pine forests since white settlement. Ecological Monographs 30: 129-164.

**National Environmental Policy Act (NEPA) Compliance**

NEPA is designed to foster informed and transparent decision-making.[2,3] It requires the Forest Service to "[e]*ncourage and facilitate public involvement in decisions which affect the quality of the human environment*,"[4] and to use high quality information because "[a]*ccurate scientific analysis . . . and public scrutiny are essential to implementing NEPA*."[5] To these ends, courts have held that environmental review documents must be written in plain, clear language and "*supported by evidence that the agency has made the necessary environmental analyses*."[6]

NEPA outlines several requirements, including a purpose and need statement to provide the guideposts for the analysis of the proposed action, alternatives, and environmental effects.[7] NEPA also requires federal agencies to "*study, develop, and describe appropriate alternatives to recommend courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources.*"[8] This includes preparation of an environmental impact statement (EIS) for all "*major Federal actions significantly affecting the quality of the human environment*."[9]

The Forest Service must accurately describe the baseline conditions in the project area. "*In analyzing the affected environment, NEPA requires the agency to set forth the baseline conditions.*"[10] "*The concept of a baseline against which to compare predictions of the effects of the proposed action and reasonable alternatives is critical to the NEPA process…Once a project begins, the pre-project environment becomes a thing of the past and evaluation of the project's effect becomes simply impossible.*"[11] *"[W]ithout [baseline] data, an agency cannot carefully consider information about significant environment impacts. Thus, the agency fails to consider an important aspect of the problem, resulting in an arbitrary and capricious decision.*"[12]

NEPA also requires federal agencies to take a "*hard look*" at the environmental consequences of proposed actions, including their direct, indirect, and cumulative effects.[13,14] The Forest Service must consider all direct, indirect, and cumulative environmental impacts of the proposed action, including the interactions between livestock grazing and vegetation or habitat management.[15] Direct effects are caused by the action and occur at the same time and place as the proposed project.[16] Indirect effects are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable.[17] Both types of impacts include "*effects on natural resources and on the components, structures, and functioning of*

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[2] 40 C.F.R.. § 1500.1
[3] See also: *Robertson v. Methow Valley Citizens Council*, 490 U.S. 322, 349 (1989)
[4] 40 C.F.R.. § 1500.2(d)
[5] 40 C.F.R.. § 1500.1(b)
[6] See, e.g., *Earth Island Inst. v. U.S. Forest Service*, 442 F.3d 1147, 1160 (9th Cir. 2006)
[7] 40 C.F.R.. § 1502.13
[8] 42 U.S.C. § 4332(2)(E)
[9] 42 U.S.C. § 4332(2)(C)
[10] Western Watersheds Project v. BLM, 552 F.Supp.2d 1113, 1126 (D. Nev. 2008)
[11] Northern Plains v. Surf. Transp. Brd., 668 F.3d 1067, 1083 (9th Cir. 2011)
[12] *Ibis* at 10850
[13] Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 348 (1989)
[14] 42 U.S.C. § 4332(2)(C); 40 C.F.R.. §§ 1502.16, 1508.7, 1508.8
[15] 40 C.F.R. §§ 1502.16, 1508.8, 1508.25(c)
[16] 40 C.F.R. § 1508.8(a)
[17] 40 C.F.R. § 1508.8(b)

*affected ecosystems*," as well as "*aesthetic, historic, cultural, economic, social or health [effects].*"[18] For example, if herbicides may be used for fuel treatment under the proposed action, then the USFS must consider all direct, indirect, and cumulative impacts of such herbicide use on the environment including on water and air quality and impacts to native species and downstream communities.

Identification of cumulative impacts must be robust. The NEPA obligation to consider cumulative impacts extends to all "*past*," "*present*," and "*reasonably foreseeable*" future projects.[19] Past cumulative effects analyses have violated NEPA because they failed to provide "*adequate data of the time, place, and scale*" and did not explain in detail "*how different project plans and harvest methods affected the environment*."[20] When considering the effects of past actions as part of a cumulative effects analysis, the Responsible Official must analyze the effects in accordance with 40 CFR 1508.7 and in accordance with relevant guidance issued by the Council on Environmental Quality.[21] Past effects should include livestock grazing, fire suppression, chaining and herbicide use, and other vegetation treatments.

The Forest Service must evaluate all potential impacts to native wildlife and plants whether detrimental or beneficial. The EA should establish a robust monitoring and adaptive management framework to better understand the impacts of treatments to wildlife as these effects are largely unknown for many species. Significant cumulative effects to numerous environmental resources may result from the proposed action in combination with past, ongoing and foreseeable management activities within and in close proximity to the project area. The Forest Service is required to take a hard look at such impacts rather than merely list potential causes or mention that some risk may result from a catalogue of activities.

**A Strategic Fire-Based Restoration Alternative would support the purpose and need**

The NEPA implementing regulations refer to the selection and review of alternatives as "*the heart*" of the environmental impact statement.[22] NEPA requires that a range of meaningful alternatives be explored in the environmental review process.[23] The Draft EA should contain a no action alternative. While a no-action alternative is not required for an EA[24] it is vitally important for a project like this, considering that "*The no-action alternative provides a baseline for estimating the effects of other alternatives*."[25] The comparison of the alternatives helps to "*sharply defin[e] the issues and provid[e] a clear basis for choice among options by the decision maker and the public.*"[26]

In the East Eagle/Mud Springs Fuels Project the Forest Service must "*study, develop, and describe appropriate alternatives to recommend courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources.*"[27] The Forest Service should incorporate the issues developed in this comment to formulate a reasonable alternative that avoids significant cumulative

[18] *Ibid*
[19] Oregon Natural Resources Council Fund v. Brong, 492 F.3d 1120, 1133 (9th Cir. 2007); Lands Council v. Powell, 395 F.3d 1019, 1028 (9th Cir.2005)
[20] *Ibid*
[21] 43 C.F.R. § 46.115; and see "The Council on Environmental Quality Guidance Memorandum on Consideration of Past Actions in Cumulative Effects Analysis" dated June 24, 2005, or any superseding Council on Environmental Quality guidance.

[22] FSH 1905.15 – Ch. 20, and also 40 C.F.R. § 1502.14
[23] 42 U.S.C. §§ 4332(C)(iii))
[24] FSH 1909.15 – Ch. 10 § 14.2
[25] *Ibid*
[26] FSH 1905.15 – Ch. 20 § 23.3 (5)
[27] 42 U.S.C. § 4332(2)(E)

effects and provides a range of alternatives for the public to consider. The analysis of an additional alternative is critical as it ensures that the Forest Service does not "*prematurely foreclose options that might protect, restore, and enhance the environment.*"[28]

Conditions that underlay the need for ecological restoration in the project area result from high-grade logging, fire suppression and livestock grazing[29], encroachment of human civilization into fire-adapted ecosystems[30] and effects of climate change to fire regime.[31] A proactive landscape-scale restoration approach must deal with fundamental ecological problems. This project does not stand alone, as many past and foreseeable actions, including unplanned fire events, affect potential fire behavior effects in the project area. The analysis should consider these factors in the discussion of the affected environment and effects of the action. The analysis should also assess the necessity of mechanical treatments and temporary road building in recently burned areas.

The EA should identify strategic treatment priorities incorporating new scientific information relevant to landscape-scale restoration within the East Eagle/Mud Springs Fuels Project Landscape. These include:

(1) Strategically placed treatments to support fire use in the long-term, utilizing anchor points such as natural fuel breaks, previously treated or burned areas, roads, and waterways

(2) Reasons why the location, timing and intensity of proposed mechanical actions will support a coherent restoration strategy

(3) Landscape scale assessment of opportunities to manage unplanned natural ignitions for resource benefits

(4) An analysis of fire-risk at multiple spatial scales using broader criteria[32]

- (a) surface fuel density and arrangement
- (b) canopy base height
- (c) crown bulk density
- (d) local topography
- (e) prevailing weather patterns

Without active fuels management and fire use for resource benefits on relatively short rotations compared to the era of total fire suppression, the Forest Service generally manages landscapes for large-scale, high-

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[28] FSH 1905.15 Ch. 20 § 14
[29] Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa forest structure: Changes since Euro-American settlement. *Journal of Forestry* 92: 39-47.
[30] Radeloff, V.C., R.B Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The wildland-urban interface in the United States. *Ecological Applications* 15: 799-805.
[31] Flannigan, M.D., B.J. Stocks, and B.M. Wotton. 2000. Climate change and forest fires. *The Science of the Total Environment* 262: 221-29.
[32] These criteria have long-been identified as fundamental factors in effective fire and fuels-management planning, for example see:
Agee, J.K., and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211(1): 83-96.
Reinhardt, E. D., R.E. Keane, D. E. Calkin, and J. D. Cohen. 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. *Forest Ecology and Management* 256:1997-2006.

intensity fires that outrun suppression resources in extreme weather and create unnecessary management expense and unacceptable risks to human life and resource values. We appreciate that the East Eagle/Mud Springs Fuels Project intends to use prescribed fires to accomplish a range of objectives. In addition, we urge the Forest Service to the design the project to promote use of unplanned wildland fires while providing for public safety. The EA should provide meaningful analysis of how, where, and when unplanned ignitions could be used to accomplish resource management objectives, and what the range of effects of fire-use could be. Adverse effects of fire control practices to the environment[33] should be analyzed and disclosed where proposed treatments are designed to increase the effectiveness of fire suppression.

Ultimately, forest structure and fire regime must be restored in an integrated way.[34] In ponderosa pine forest and mixed-conifer forest, this means emphasizing landscape-scale use of wildland fire as the primary self-sustaining disturbance process that will naturally promote ecosystem adaptation and resilience—and then scaling down to coordinated project-level actions including fuel treatments that accomplish landscape-level objectives.[35] The project analysis should demonstrate that the proposed action fits into a coordinated management strategy that moves towards allowing natural ignition fires to burn, but it currently seems overly reliant on repeated mechanical entry over the next 20 years.

It is vitally necessary to inform this analysis with landscape-scale assessment of where unplanned wildland fires can be managed for resource benefits in order to ensure that fuel treatments are efficiently prioritized and located to accomplish multiple objectives—including community protection, wildlife habitat conservation and ecological restoration. Linking fire management at a landscape scale with fuel treatments at the project scale will increase the probability that management will successfully establish a functional fire regime at minimum cost while providing for public safety and resource protection. We understand that the Forest Service does not typically "like" to include "prioritization" or "sequencing" of individual treatments into NEPA analysis, but if the East Eagle/Mud Springs Fuels Project is going to consider landscape-fuel treatments, it must move far beyond vague and indiscernible treatments categories and adopt a robust and comprehensive approach to identifying where treatments can achieve the most beneficial outcomes at the least cost. Otherwise, this is just taking "shots in the dark" at some unknown target. We suggest the East Eagle/Mud Springs Fuels Project consider a tiered prioritization approach using TEU's as a basis for determining site-specific desired conditions. If the Forest Service choses to use such an approach, the EA should describe the process in detail.

A robust prioritization approach – consistent with core ecological restoration principles – is needed in the East Eagle/Mud Springs Fuels Project analysis: "*Prioritizing restoration efforts is essential because resources are limited. An initial focus on areas most likely to provide benefits and that present a low risk of degradation of ecological values will build experience and credibility.*"[36] A rigorously designed approach to prioritize and place treatments that facilitate landscape-scale fire processes is an oft-neglected component of ponderosa pine forest, woodland, and grassland restoration efforts. The East Eagle/Mud

[33] Backer, D.M, S.A. Jensen, and G.R. McPherson. 2004. Impacts of fire suppression activities on natural communities. *Conservation Biology* 18: 937-46.

[34] DellaSala, D.A., J.E. Williams, C.D. Williams and J.F. Franklin. 2004. Beyond smoke and mirrors: a synthesis of fire policy and science. *Conservation Biology* 18: 976-86.

[35] Peterson, D.L. and M.C. Johnson. 2007. Science-based strategic planning for hazardous fuel treatment. *Fire Management Today* 67(3):13-18.

[36] Brown, Richard T., James K. Agee, and Jerry F. Franklin. 2004. Forest restoration and fire: principles in the context of place. *Conservation Biology* 18(4):903-912.

Springs Fuels Project should follow a process where "*Strategies for conserving both aquatic and terrestrial resources at multiple scales are based on …secur[ing] areas with high ecological integrity ("anchor habitats"), extend[ing] these areas, and connect[ing] them at the landscape level*"[37].

Forest Service scientists have established that any science-based planning should ask "*Which locations provide the greatest strategic opportunity for fuel treatments that would facilitate attainment of desired conditions*?"[38] The EA should address this question and take it one step further, expanding prescribed and wildland fire use through strategic placement of mechanical treatments. This fire process-oriented approach is a necessary step in the analysis, because "*Prioritizing treatment areas allows the consideration of landscape-scale patterns of vegetation change, fuel continuity, and potential fire spread*,"[39] aspects which, when fully studied, would meet the project Purpose and Need. If appropriate, this approach should also incorporate the newest information on structure and community protection[40] in the context of climate adaptation,[41] and the capacity for human effects to override climate influence on fire behavior[42] independent of mechanical thinning treatments.

Integrated approaches that provide promising direction for strategic treatment prioritization, such as optimized fuel treatments developed by academic[43] and Forest Service[44] scientists are being refined. Such approaches have shown that "*optimum placement of fuels treatments*" [and] "*efficiently allocating resources, in this case thinning, and using thinned areas to restore surface fire in the short-term, can… restore adaptive capacity for more extreme late-century fire weather*."[45] In addition, new research indicates that regeneration patterns following recent uncharacteristically severe fires "*could be more resilient to climate change and severe wildfires than the overly-dense ponderosa pine forests that were present before the wildfires*,"[46] suggesting that assumptions about severe fire effects on climate resilience should be questioned. Recent science syntheses also suggest that "complex early-seral forests"[47] which can only arise following mixed-severity fire events, are a valuable component of a biologically diverse and fire-resilient landscape.[48] While this phenomenon has not been given much attention from the scientific community in the southwest, the topic clearly merits further consideration.

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[37] *Ibid*

[38] Peterson, D.L. and M.C. Johnson. 2007. Science-based strategic planning for hazardous fuel treatment. *Fire Management Today* 67(3):13-18.

[39] Sisk, T.D., M. Savage, D.A. Falk, C.D. Allen, E. Muldavin, and P. McCarthy. 2005. A landscape perspective for forest restoration. *Journal of Forestry* 103(6):319-320.

[40] Alexandre, P.M., *et al.* 2016. Factors related to building loss due to wildfires in the conterminous United States. *Ecological Applications* 26(7): 2323-2338.

[41] Schoennagel, T. *et al.* 2017. Adapt to more wildfire in western North American as climate changes. *PNAS* doi/10.1073/pnas.1617464114.

[42] Syphard, A., *et al.* 2017. Human presence diminishes the importance of climate in driving fire activity across the United States. *PNAS* doi.org/10.1073/pnas.1713885114.

[43] Chung, W. 2015. Optimizing fuel treatments to reduce wildland fire risk. *Current Forestry Reports* 1:44-51; Chung, W., *et al.* 2013. Optimising fuel treatments over time and space. *Int. J. of Wildland Fire* 22: 1118-1133.

[44] Finney, M.A. 2007. A computational method for optimising fuel treatment locations. *Int. J. of Wildland Fire* 16: 702-711.

[45] Krofcheck, D.J. *et al.* 2017. Prioritizing forest fuel treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. *Global Change Biology* DOI: 10.1111/gcb.13913: p.1-9.

[46] Owen, S.M., *et al.* 2017. Spatial patterns of ponderosa pine regeneration in high-severity burn patches. *Forest Ecology and Management* 405: 134-149.

[47] DellaSala, D.A., and C.T. Hanson, editors. 2015. The ecological importance of mixed-severity fires. Elsevier, Waltham, MA.

[48] Swanson, M.E. *et al.* 2011. The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and the Environment* 9(2): 117-125.

This landscape-scale analysis provides the opportunity to be a model for utilizing the best available science and most advanced approaches to restoration planning and implementation. It would support use of moderate and mixed severity fire to move towards desired conditions[49] while placing mechanical treatments most effectively for infrastructure protection, fire management, cost-efficiency, and protection of ecologically sensitive sites. A failure to incorporate these cutting-edge methodologies and science in active restoration of the East Eagle/Mud Springs Fuels Project would be a fantastic opportunity lost. The size of the project, nearly 100,000 acres, area is easily conducive to utilizing such an approach.

**Livestock Grazing Impacts May Impede Project Success**

Livestock grazing is one important factor to consider that may adversely impact forest health and fire regime. It directly contributes to fire hazard in the project area by impairing soil productivity and altering vegetation communities, which indirectly contribute to delayed fire rotations, increased forest density, and reduced forage opportunities for herbivorous species and predators. Potentially significant cumulative effects to soil productivity, plant communities, fire regime and wildlife may result from fuel management in combination with livestock grazing and other activities, such as road building and motorized vehicle use, which disturb soils and spread exotic plant species. Livestock disturb soil, enable seeds of exotic species to spread, and reduce the competitive and reproductive capacities of native species. Exotic plant species, once established, can displace native species, in part, because native grasses are not adapted to frequent and close grazing in combination with fire disturbance.

Exotic plant spread is a potentially significant cumulative impact of the proposed action. Treatments similar to the proposed action in northern Arizona left forest sites overrun with cheatgrass (*Bromus tectorum*). Exotic grass invasion is foreseeable and has important long-term implications for native plant communities in fire-adapted ecosystems and wildlife. Melgoza and others[50] studied cheatgrass soil resource acquisition after fire and noted its competitive success owing to its ability suppress the water uptake and productivity of native species for extended periods of time. They further showed that cheatgrass dominance is enhanced by its high tolerance to grazing. Its annual life-form coupled with the abilities to germinate readily over a wide range of moisture and temperature conditions, to quickly establish an extensive root system, and to grow early in the spring contribute to its successful colonization. In addition, Melgoza and others showed that cheatgrass successfully competes with the native species that survive fire, despite these plants being well-established adult individuals able to reach deeper levels in the soil. This competitive ability of cheatgrass contributes to its dominance when lands experience synergistic disturbances from grazing, mechanical treatments, and fire.

Persistent livestock grazing is a component of the compromised ecological condition of the Southwest's forests and riparian areas. The Forest Service should analyze the effects of livestock grazing on the success of the proposed vegetation treatments in achieving and maintaining desired future conditions as

[49] Huffman, D.W. *et al.* 2017. Efficacy of resource objective wildfires for restoration of ponderosa pine forests in northern Arizona. *Forest Ecology and Management* 389: 395-403, and Huffman, D.W. *et al.* 2017. Restoration benefits of re-entry with resource objective wildfire on a ponderosa pine landscape in northern Arizona, USA. *Forest Ecology and Management* 408: 16-24.

[50] Melgoza, G., R.S. Nowak and R.J. Tausch. 1990. Soil water exploitation after fire: competition *between Bromus tectorum* (cheatgrass) and two native species. *Oecologica* 83:7-13.

they relate to fire use, migratory bird, native fish and other sensitive species populations and habitats. Livestock grazing has had numerous, long-lasting negative impacts to arid western ecosystems:[51]

• Livestock grazing decreases understory biomass and density, reducing competition with conifer seedlings and reducing the ability of the understory to carry low-intensity fire, contributing to dense forests with altered species composition.[52]

• Grazing significantly reduces water infiltration into the soil, and rest from grazing allows infiltration rates to recover. USDA research has found that excluding cattle from a landscape for five growing seasons "*significantly increased: (1) total vegetative cover, (2) native perennial forb cover, (3) grass stature, (4) grass flowering stem density, and (5) the cover of some shrub species and functional groups.*"[53]

• Removal of livestock grazing pressure from riparian areas has been found to have a positive effect on growth, distribution, and vigor of riparian communities.[54]

• Livestock grazing also degrades water quality by increasing water temperatures in several ways. It widens channels due to bank damage from trampling and sedimentation, leading to elevated water temperature via the loss and suppression of riparian vegetation that provides stream shade.[55/56] Trampling impacts are substantial even in the absence of shade loss.[57] This is a serious impact because elevated water temperature adversely affects numerous aquatic species, including those which occur in this project area.

• Grazing of the most nutritious plants by livestock results in a loss of forage for native species and can alter habitat or insect prey base.[58/59] A decrease in prey base inevitably leads to a decrease in carnivores in the area, which are also eliminated by the government at the request of the livestock community.

• Livestock facilitate the spread of exotic species, particularly in combination with fire, and reduce the competitive and reproductive capacities of native species.[60] Exotic plant species, once established, can displace native species, in part, because native grasses are not adapted to frequent and close grazing in

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[51] Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8(3):629-644.
[52] Belsky A.J. and D.M. Blumenthal. 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the Interior West. *Conservation Biology* 11:316-27.
[53] Kerns, Becky K., Michelle Buonopane, Walter G. Thies, and Christine Niwa. 2011. Reintroducing fire into a ponderosa pine forest with and without cattle grazing: understory vegetation response. *Ecosphere* 2(5):1-23.
[54] Schulz, Terri Tucker, and Wayne C. Leininger. 1990. Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43(4):295-299.
[55] Kondolf, G. Mathias, Richard Kattelmann, Michael Embury, and Don C. Erman. 1996. Status of riparian habitat. Sierra Nevada Ecosystem Project: Final report to Congress, Volume 2
[56] Beschta, R.L., D.L. Donahue, D.A. DellaSala, J.J. Rhodes, J.R. Karr, M.H. O'Brien, T.L. Fleischner and C.D. Williams. 2013. Adapting to climate change on western public lands: addressing the ecological effects of domestic, wild, and feral ungulates. *Environmental Management* 51: 474-91.
[57] Rhodes, J.J., D.A. McCullough, and F.A Espinosa, Jr. 1994. A coarse screening process of the effects of land management on salmon spawning and rearing habitat in ESA consultations. Technical Report 94-4. Columbia River Inter-Tribal Fish Commission. Portland, Oregon. Report prepared for National Marine Fisheries Service.
[58] Donahue, D. 1999. The Western Range Revisited: Removing Livestock from Public Lands to Conserve Native Biodiversity. Norman, OK: University of Oklahoma Press. 338 pages.
[59] Kie, John G., Charles J. Evans, Eric R. Loft, and John W. Menke. 1991. Foraging behavior by mule deer: the influence of cattle grazing. *The Journal of Wildlife Management* 55(4):665-674.
[60] Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J. B. Grace, J.E. Keeley, J. M. DiTomaso, R.J. Hobbs, M. Pellant and D.Pyke. 2004. Effects of invasive alien plants on fire regimes. *BioScience* 54(7):677-688.

combination with fire disturbance.[61/62/63] "*The productivity, diversity, and species richness of native grasslands are threatened by competition from noxious and invasive weeds/grasses. Productivity is threatened by other factors including drought, soil erosion, fire suppression, and improper livestock management practices.*"[64]

• Grazing also has negative effects on songbirds, reptiles and other mammals especially if their habitat is close to the ground.[65] Rosenstock and Van Riper reported that "*Livestock grazing and fire suppression commonly are cited as causes of woodland expansion.*"[66]

• A critical and often overlooked consideration in effective vegetation treatments is the necessity for resting a treated area from domestic livestock grazing to allow establishment of fine fuels such that low-intensity ground fire can be applied to the forest floor, and aligning allotment management plans such that future livestock grazing does not deplete the fine fuels that are required to maintain a prescribed fire schedule. The Ecological Restoration Institute reviewed the research and perspectives on resting from grazing, and concluded that:

"*These research findings, although limited, suggest that federal agencies should be prepared to wait more than two years before allowing domestic grazing on restored allotments lest they jeopardize two important goals of restoration treatments—restoring the understory and returning low-intensity prescribed fire as an ecosystem process.*"[67]

Recent studies into livestock grazing management[68/69] have identified ways to reduce negative impacts, primarily through changes in agency management of forage resources and grazing to reflect best available science. These changes would contribute significantly to improving the habitat for a range of species in the East Eagle/Mud Springs Fuels Project. Recommended management changes include:

(1) Eliminating areas with sensitive or high-erosion soils from capacity, suitability, or stocking rate calculations;

(2) Updating stocking rates based on conservative forage utilization rates (25-30 percent);

(3) Managing livestock by herding rather than fencing or water developments;

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[61] Mack, R. N., and J. N. Thompson. 1982. Evolution in steppe with few large, hooved mammals. *American Naturalist* 119:757-72.

[62] Melgoza, G., R.S. Nowak and R.J. Tausch. 1990. Soil water exploitation after fire: competition *between Bromus tectorum* (cheatgrass) and two native species. *Oecologica* 83:7-13.

[63] Belsky, A.J., and J.L. Gelbard. 2000. Livestock Grazing and Weed Invasions in the Arid West. Oregon Natural Desert Association: Portland, OR. April. 31 pp.

[64] Central Arizona Grasslands Conservation Strategy, page 21

[65] Finch, D.M., and W. Block, technical editors. 1997. Songbird ecology in southwestern ponderosa pine forests: a literature review. Gen. Tech. Rep. RM-GTR-292. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 152 p.

[66] Rosenstock, S. S. and Van Riper III, C. (2001) Breeding Bird Responses to Juniper Woodland Expansion. *Journal of Range Management*, 54:226-232.

[67] Egan, D. 2011. Integrating Domestic and Wild Ungulate Grazing into Forest Restoration Plans at the Landscape Level. Issues in Forest Restoration, ERI White papers. Ecological Restoration Institute, Flagstaff, AZ. 14p.

[68] Carter, J., J. Chard, and B. Chard. 2011. Moderating Livestock Grazing Effects on Plant Productivity, Nitrogen and Carbon Storage. *In* Monaco, T.A. *et al.,* 2011. Proceedings – Threats to Shrubland Ecosystem Integrity; May 18-20, 2010, Logan, UT. *Natural Resources and Environmental Issues* 17.

[69] Carter, J., J.C. Catlin, N. Hurwitz, A.L. Jones, and J. Ratner. 2017. Upland water and deferred rotation effects on cattle use in riparian and upland areas. *Rangelands* 39(3-4): 112-118.

(4) Provide for rest, in some cases, several years, to allow for recovery of vegetation within allotments following vegetation treatments, fire or other disturbances;

(5) Closure of areas with degraded soil or plant.

The Forest Service should identify areas with degraded soils or plant communities, areas with sensitive or high-erosion soils, and areas in need of recovery, and reduce or eliminate grazing in those pastures altogether to contribute to the success of forest restoration treatments.

**Forest Thinning Treatments**

The intensity of wildland fire behavior and the severity of its physical and biological effects depend, in part, on fuel properties and their spatial arrangement. Fuel bed structure is a key determinant of fire ignition and spread potential and a central consideration in developing an effective management strategy.[70] The bulk density (weight within a given volume) of ground fuels (*e.g.*, grasses, shrubs, litter, duff, and down woody material) influences frontal surface fire behavior (heat output and spread rate) more than fuel loading (weight per unit area).[71/72] In turn, surface fireline intensity dictates the likelihood of tree crown ignition and torching behavior.[73]

The density, composition and structure of intermediate fuel strata consisting of tall shrubs and small trees also affect crown fire ignition potential because they can support surface fireline intensity and serve as "ladders" that facilitate vertical fire spread from the ground surface into overstory tree canopies. The size of the spatial gap in between ground fuel beds and tree canopies strongly influences the crown ignition potential of a surface fire.[74] Van Wagner[75] quantified crown fire ignition rates when surface fires exceed critical fireline intensity relative to the height of the base of aerial fuels in tree crowns. Torching crowns (*i.e.*, "passive crown fire") can develop into running canopy fires (*i.e.*, "active crown fire" that spreads independent of surface fire behavior) if the spread rate surpasses a crown fuel density threshold that varies with slope angle and wind speed. Predictions about the relationship of forest structure to crown fire hazard depend, in part, on the validity of crown bulk density calculations and estimates.[76] The project analysis should ensure integrity with site-specific information based on field observations.

Active management of the arrangement and density of surface fuels and "ladder fuels" is effective at minimizing potential fire intensity in most circumstances.[77] Some have advocated removing large or

[70] Graham, R.T. (Ed.). 2003. *Hayman Fire Case Study*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT.

[71] Agee, J.K. 1996. The influence of forest structure on fire behavior. Pp. 52-68 in: J.W. Sherlock (chair). *Proc. 17th Forest Vegetation Management Conference.* 1996 Jan. 16-18: Redding, CA. Calif. Dept. Forestry and Fire Protection: Sacramento.

[72] Sandberg, D.V., R.D. Ottmar, and G.H. Cushon. 2001. Characterizing fuels in the 21st century. *International Journal of Wildland Fire* 10: 381-87.

[73] Scott, J.H., and E.D. Reinhardt. 2001. *Assessing Crown Fire Potential by Linking Models of Surface and Crown Fire Behavior*. USDA For. Serv. Rocky Mtn. Res. Sta. Res. Pap. RMRS-RP-29. Fort Collins, CO.

[74] Graham, R.T. (Ed.). 2003. *Hayman Fire Case Study*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT.

[75] Van Wagner, C.E. 1977. Conditions for the start and spread of crown fire. *Canadian Journal of Forest Research* 7: 23-24.

[76] Perry, D.A., H. Jing, A. Youngblood, and D.R. Oetter. 2004. Forest structure and fire susceptibility in volcanic landscapes of the eastern high Cascades, Oregon. *Conservation Biology* 18: 913-26.

[77] Graham, R.T., S. McCaffrey, and T.B. Jain (Tech. Eds.). 2004. *Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-120. Ft. Collins, CO.

dominant trees to reduce crown bulk density and contended that doing so will lessen fire resistance-to-control in extreme weather.[78] However, fire weather can overwhelm any effect of fuel treatments on fire behavior.[79] To accurately assess fuel treatment effects on the likelihood of crown fire initiation and spread, it is necessary to consider: (1) surface fuel density and arrangement; (2) canopy base height; (3) local topography; and (4) weather patterns.[80] The former two factors can be actively managed in conifer forest to significantly decrease the likelihood of crown fire initiation and spread without resort to large tree removal in most cases.[81/82/83/84]

Omi and Martinson[85] measured the effect of fuel treatments on fire severity in highly stratified study areas and reported a strong correlation of crown base height with "stand damage" by fire. Importantly, crown bulk density did not strongly correlate with observed fire effects:

*"[H]eight to live crown, the variable that determines crown fire initiation rather than propagation, had the strongest correlation to fire severity in the areas we sampled... [W]e also found the more common stand descriptors of stand density and basal area to be important factors. But especially crucial are variables that determine tree resistance to fire damage, such as diameter and height. Thus, "fuel treatments" that reduce basal area or density from above (i.e., removal of the largest stems) will be ineffective within the context of wildfire management"* (Omi and Martinson 2002: 22).

That research was retroactive and the scale of observed fire events confounds replication. However, its observation that large trees promote fire resistance is supported by Forest Service research.[86] A key implication is the importance of treating fuels "from below" in order to prevent widespread occurrence of stand-replacing fires. Keyes and O'Hara (2002: 107) agreed that raising canopy base height is an important factor in reducing fire hazard and noted, "[P]*runing lower dead and live branches* [of large trees] *yields the most direct and effective impact.*" They also noted the incompatibility of open forest conditions created by "heavy" thinning treatments designed to maximize horizontal discontinuity of forest canopies with other management objectives that include conservation of threatened wildlife populations and prevention of rapid understory initiation and ladder fuel development. Understory growth following

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Graham, R.T., A.E. Harvey, T.B. Jain, and J.R. Tonn. 1999. *The Effects of Thinning and Similar Stand Treatments on Fire Behavior in Western Forests.* USDA For. Serv. Pac. Nor. Res. Sta. Gen. Tech. Rep. PNW-GTR-463. Portland, OR.

[78] Abella, S.R., P.Z. Fulé and W.W. Covington. 2006. Diameter caps for thinning southwestern ponderosa pine forests: viewpoints, effects, and tradeoffs. *Journal of Forestry* (December): 407-14.

[79] Pollett, J. and P.N. Omi. 2002. Effect of thinning and prescribed burning on crown fire severity in ponderosa pine forests. *International Journal of Wildland Fire* 11: 1-10.

[80] Hunter, M.E., W.D. Shepperd, J.E. Lentile, J.E. Lundquist, M.G. Andreu, J.L. Butler, and F.W. Smith. 2007. *A Comprehensive Guide to Fuels Treatment Practices for Ponderosa Pine in the Black Hills, Colorado Front Range, and Southwest*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-198. Fort Collins, CO.

[81] Fiedler, C.E., and C.E. Keegan. 2003. Reducing crown fire hazard in fire-adapted forests of New Mexico. Pp. 29-38 in: P.N. Omi and L.A. Joyce (tech. eds.). *Fire, Fuel Treatments, and Ecological Restoration: Conference Proceedings*. 2002 April 16-18: Fort Collins, CO. USDA For. Serv. Rocky Mtn. Res. Sta. Proc. RMRS-P-29. Fort Collins, CO.

[82] Keyes, C.R. and K.L. O'Hara. 2002. Quantifying stand targets for silvicultural prevention of crown fires. *Western Journal of Applied Forestry* 17: 101-09.

[83] Omi, P.N., and E.J. Martinson. 2002. *Effect of Fuels Treatment on Wildfire Severity*. Unpubl. report to Joint Fire Science Program. Fort Collins: Colorado State Univ. Western Forest Fire Research Ctr. March 25. 36 pp.

[84] Perry, D.A., H. Jing, A. Youngblood, and D.R. Oetter. 2004. Forest structure and fire susceptibility in volcanic landscapes of the eastern high Cascades, Oregon. *Conservation Biology* 18: 913-26.

[85] Omi, P.N., and E.J. Martinson. 2002. *Effect of Fuels Treatment on Wildfire Severity*. Unpubl. report to Joint Fire Science Program. Fort Collins: Colorado State Univ. Western Forest Fire Research Ctr. March 25. 36 pp.

[86] Arno, S.F. 2000. Fire in western ecosystems. Pp. 97-120 in: J.K. Brown and J.K. Smith (eds.). *Wildland Fire in Ecosystems, Vol. 2: Effects of Fire on Flora*. USDA For. Serv. Gen. Tech. Rep. RMRS-42-vol.2. Ogden, UT.

treatments that create open forest conditions may undermine their long-term effectiveness without commitments to maintenance treatments (*e.g.*, prescribed fire).

Mechanical logging generates large quantities of activity-created slash fuels by relocating tree stems, branches and needles from the overstory canopy to the ground surface.[87] Logging slash produces higher flame lengths and more intense surface fires that can increase the probability of crown fire initiation compared to fuels that pre-exist logging operations.[88] According to the Congressional Research Service:

"*Timber harvesting removes the relatively large diameter wood that can be converted into wood products, but leaves behind the small material, especially twigs and needles. The concentration of these "fine fuels" on the forest floor increases the rate of spread of wildfires. Thus, one might expect acres burned to be positively correlated with timber harvest volume*."[89]

The proposed action may immediately increase volume of fine surface fuels up to 15 tons per acre, or more depending on pre-treatment forest structure, which will increase fire resistance-to-control and make wildfires more dangerous and severe where activity fuels are not effectively managed. Van Wagtendonk (1996) modeled the effectiveness of low thinning combined with a pile-and-burn slash treatment on flat ground, which yielded nearly identical post-treatment fire behavior as thinning without any slash treatment because pre-existing surface fuels were not significantly reduced. Lop-and-scattering of logging slash "*significantly increased subsequent fire behavior*" (van Wagtendonk 1996: 1160). Activity fuels may persist for decades in xeric forest environments (Stephens and Moghaddas 2005: 377):

"*In both even aged and un-even aged treatments, it is often assumed that harvest related slash will decompose over time thereby reducing fire hazards. In reality, logging slash may persist for long periods, and therefore, will influence fire hazards for extended periods. Rates of woody fuel decay are highly variable. The rates of decomposition of understory fuels are primarily dependant upon several factors including temperature, soil moisture, insect activity, and material size. Decaying conifer activity fuels have been reported to persist for 30 years in xeric forest environments.*"

Prescribed burning is the only treatment that effectively reduces activity fuels and fire hazard below pre-logging conditions (Stephens 1998, van Wagtendonk 1996). "*Periodic underburns and programs for restoring natural fire are critical to maintain these post-harvest stands*" (Pollett and Omi 2002: 9).

[87] Graham, R.T. (Ed.). 2003. *Hayman Fire Case Study*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-114. Ogden, UT.
Stephens, S.L. 1998. Evaluation of the effects of silvicultural and fuels treatments on potential fire behavior in Sierra Nevada mixed-conifer forests. *Forest Ecology and Management* 105: 21-35.
van Wagtendonk, J.W. 1996. Use of a deterministic fire growth model to test fuel treatments. Ch. 43 in: *Status of the Sierra Nevada: Sierra Nevada Ecosystem Project, Final Report to Congress, Vol. 1, Assessment Summaries and Management Strategies*. Davis: Univ. Calif. Ctr. for Wildland and Water Resources.
Weatherspoon, C.P. and C.N. Skinner. 1995. An assessment of factors associated with damage to tree crowns from the 1987 wildfires in northern California. *Forest Science* 41: 430-51.
[88] Dodge, M. 1972. Forest fuel accumulation: a growing problem. *Science* 177: 139–42.
Naficy, C., A. Sala, E.G. Keeling, J. Graham and T.H. DeLuca. 2010. Interactive effects of historical logging and fire exclusion on ponderosa pine forest structure in the northern Rockies. *Ecological Applications* 20: 1851-64.
Stephens, S.L. and J.J. Moghaddas. 2005. Silvicultural and reserve impacts on potential fire behavior and forest conservation: Twenty-five years of experience from Sierra Nevada mixed conifer forests. *Biological Conservation* 125: 369-79.
[89] Gorte, R.W. 2000. *Memorandum on Timber Harvesting and Forest Fires*. Congressional Research Service, Library of Congress: Washington, D.C. August 22.

Burning is uniquely effective because fire consumes the finest and most ignitable activity fuels that pose the greatest hazard.[90]

The Forest Service is required to disclose potentially significant effects of the project on public health and safety, including wildland fire control efforts. It should take a hard look at post-logging fuel profiles and fire hazard at a unit-scale, particularly on steep slopes where prescribed fire may not be used, rather than generalizing them across the project area. Site-specific field data collection and reporting is a fundamental professional standard for fuel management in this project:

*"Mapping should utilize the best sampling strategies combining remote sensing imagery (perhaps at several scales) and ground truthing. The reliability of existing vegetation maps should be verified before they are incorporated into the database. Fire-relevant attributes of vegetation (including understory composition and structure, and vertical and horizontal continuity) need to be characterized adequately. Similarly, surface fuels should be described, utilizing field-verified vegetation/fuels correlations to the extent feasible. The analysis should disclose how much slash would remain on the ground after logging is completed and take a hard look at the timing, sequence and effectiveness of different activity fuel treatments at sites where mechanical logging is proposed"* (Weatherspoon and Skinner 1996: 1488).

The analysis should disclose how much slash would remain on the ground after logging is completed and take a hard look at the timing, sequence and effectiveness of different activity fuel treatments at sites where mechanical logging is proposed.

The direction of potential fire spread (backing, flanking, heading) is an important consideration in treatment design because fire interacts with weather, topography and vegetation to "back" and "flank" around certain conditions, or "head" through others as it spreads. Steep slopes can facilitate wind-driven convection currents that drive radiant heat upward and bring flames nearer to adjacent, unburned vegetation, thus pre-heating fuels and amplifying fire intensity as it spreads upslope.[91] As a result, severe fire effects often are observed to concentrate at upper slope positions and on ridges, whereas such effects are relatively rare on the lee side of slopes that do not directly receive frontal wind.[92] Therefore, fuel treatments should be oriented in concert with prevailing spatial patterns of fire spread in the project area. Overlapping fuel treatments that reduce fuel continuity can fragment extreme fire effects into smaller patches if they disrupt heading fire behavior and increase the area burned by flanking and backing fires[93]. Slope aspects facing away from frontal or diurnal winds are a lesser treatment priority because backing fires are the most likely to exhibit mild intensity and effects. The Forest Service should analyze these factors and demonstrate that proposed treatment locations and intensities will meet the purpose and need. The analysis will be most helpful to the decision-maker and the public if it includes detailed study and development of action alternatives that propose different treatment locations and intensities to compare project effects on potential fire behavior and effects under modeled conditions that include extreme and moderate weather scenarios.

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[90] Deeming, J.E. 1990. Effects of prescribed fire on wildfire occurrence and severity. Pp. 95-104 in: J.D. Walstad, S.R. Radosevich, and D.V. Sandberg (eds.). *Natural and Prescribed Fire in Pacific Northwest Forests*. Corvallis: Oregon State Univ. Press.

[91] Whelan, R.J. 1995. *The Ecology of Fire*. Cambridge Univ. Press: New York.

[92] Finney, M.A. 2001. Design of regular landscape fuel treatment pattern for modifying fire growth and behavior. *Forest Science* 47: 219-28.

[93] *Ibid*

An additional approach to the strategic location of fuel treatments is to identify landscape features that are currently resistant to severe fire effects and use them as anchor points for a compartmentalized landscape fire management strategy. Such features may include natural openings, meadows, relatively open ridges, moist riparian areas, mature forest patches with shaded and cool microclimates and little or no history of past logging (*see* Naficy et al. 2010), and areas where fuel treatments already have been completed. Those features can support the strategic use of fire for resource benefits, application of confinement and containment strategies as alternatives to full control of unplanned fires, and provide safe areas for workers to ignite prescribed fires for hazard reduction and ecological process restoration. The analysis should consider such factors.

Finally, in our view, the Forest Service should prioritize fuel treatments at locations where relatively little resource investment may create fire resistant conditions in the shortest amount of time. Targeting initial work in this way will maximize the area treated with available funds and personnel, and provide the greatest opportunity to quickly reduce fuels and restore ecosystem function at larger spatial scales.

**Large trees must be protected with a defined plan**

Most old growth forests that historically existed in the Southwestern Region were eliminated by logging.[94] The ecological significance of old growth habitat and large trees that comprise their structure is amply documented[95]. Large tree removal is not necessary or beneficial to restoration of fire-adapted forest ecosystems.[96] Live conifer stems larger than 16-inches diameter are rare at a landscape scale in forests of the Southwestern Region. The Center encourages the Forest Service to study, develop and describe action alternatives in detail that generally retain existing large trees outside of a wildland-urban interface ("WUI") zone that includes forest lands located one-quarter (¼) mile distant from established residential and other essential community infrastructure.

The Forest Service is in possession of the collaboratively-designed Old Growth Protection and Large Tree Retention Strategy ("Strategy") developed by public stakeholders, including the Center, for implementation in 4FRI forest treatment projects. The Strategy is an agreement-based outcome and product developed in recognition that translation of such agreement greatly enhances chances for success, and reduces the risk of conflict. Given the enormous commitment of stakeholder time and energy to collaborative development of the Strategy, as well as its clear relevance and applicability to the East Eagle/Mud Springs Fuels Project area, it is reasonable to study, develop and describe in detail (rather than mention and dismiss) a stand-alone action alternative based on the entire Strategy as it was originally designed. Implementation of the collaborative Strategy in its entirety is a reasonable alternative in this project for three reasons. First, it meets the purpose and need by actively managing hazardous fuels and forest structure, even to the extent that it specifically allows for removal of large trees in limited

[94] Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa forest structure: Changes since Euro-American settlement. *Journal of Forestry* 92: 39-47.

[95] Friederici, P. (Ed.). 2003. *Ecological Restoration of Southwestern Ponderosa Pine Forests*. Island Press: Washington, DC.

[96] Arno, S.F. 2000. Fire in western ecosystems. Pp. 97-120 in: J.K. Brown and J.K. Smith (eds.). *Wildland Fire in Ecosystems, Vol. 2: Effects of Fire on Flora*. USDA For. Serv. Gen. Tech. Rep. RMRS-42-vol.2. Ogden, UT.

Allen, C.D. M.A. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingle. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. *Ecological Applications* 12: 1418-33.

Brown, R.T., J.K. Agee, and J.F. Franklin. 2004. Forest restoration and fire: principles in the context of place. *Conservation Biology* 18: 903-12.

circumstances, as distinct from a broad "diameter cap."[97] Second, the Strategy avoids significant cumulative impacts that may result from excessive and unnecessary removal of large, fire-resistant trees, which are deficient in the Southwestern Region compared to historic conditions.[98/99/100] Finally, it mitigates adverse effects to threatened and sensitive wildlife species that require closed canopy forest habitat for essential life behaviors. The Strategy is attached to these comments. Support for the use of the Strategy is given in further detail below:

**(1) Large tree retention meets the purpose and need**

Retention of large trees is fundamentally important to fire resistance of treated stands.[101] Large ponderosa pine trees possess autecological characteristics such as relatively thick bark and insulated buds that promote resistance to heat injury. Self-pruning, mature conifers feature high branch structure, which discourage torching behavior.[102] Finally, mature conifers have a high capacity to survive and recover from crown scorch.[103] Thus, large tree structure enhances forest resilience to severe fire effects[104/105/106] whereas removing them may undermine fire resilience.[107]/[108]

Research demonstrates no advantage in fire hazard mitigation resulting from mechanical forest treatments that remove large trees compared to treatments that retain them. Modeled treatments that removed only trees smaller than 16-inches diameter were marginally more effective at reducing long-term fire hazard than so-called "comprehensive" treatments that removed trees in all size classes.[109] Thinning small trees and pruning branches of large trees to increase canopy base height significantly decreases the likelihood of crown fire initiation,[110]/[111]/[112]/[113] which is a precondition to active crown fire behavior.[114]/[115] Therefore,

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[97] The 4FRI stakeholders expressly developed the Strategy to avoid reliance on strict diameter-limits while addressing the significant issues of old growth protection and large tree retention in ponderosa pine and mixed conifer forest restoration treatments. The Strategy identifies circumstances, ecological objectives and selection criteria for cutting large trees under site-specific conditions.

[98] Covington and Moore 1994

[99] Fulé, P.Z., W.W. Covington, and M.M. Moore. 1997. Determining reference conditions for ecosystem management of Southwestern ponderosa pine forests. *Ecological Applications* 7: 895-908.

[100] USDA 1999, USDA 2007

[101] DellaSala, D.A., J.E. Williams, C.D. Williams and J.F. Franklin. 2004. Beyond smoke and mirrors: a synthesis of fire policy and science. *Conservation Biology* 18: 976-86.

[102] Keeley, J.E. and P.H. Zedler. 1998. Evolution of life histories in *Pinus*. Pp. 219-250 in: D.M. Richardson (ed.). *Ecology and Biogeography of* Pinus. Univ. Cambridge: U.K.

[103] McCune, Bruce. "Ecological diversity in North American pines." American Journal of Botany (1988): 353-368.

[104] Arno, S.F. 2000. Fire in western ecosystems. Pp. 97-120 in: J.K. Brown and J.K. Smith (eds.). *Wildland Fire in Ecosystems, Vol. 2: Effects of Fire on Flora*. USDA For. Serv. Gen. Tech. Rep. RMRS-42-vol.2. Ogden, UT.

[105] Omi, P.N., and E.J. Martinson. 2002. *Effect of Fuels Treatment on Wildfire Severity*. Unpubl. report to Joint Fire Science Program. Fort Collins: Colorado State Univ. Western Forest Fire Research Ctr. March 25. 36 pp.

[106] Pollett, J. and P.N. Omi. 2002. Effect of thinning and prescribed burning on crown fire severity in ponderosa pine forests. *International Journal of Wildland Fire* 11: 1-10.

[107] Brown, R.T., J.K. Agee, and J.F. Franklin. 2004. Forest restoration and fire: principles in the context of place. *Conservation Biology* 18: 903-12.

[108] Naficy, C., A. Sala, E.G. Keeling, J. Graham and T.H. DeLuca. 2010. Interactive effects of historical logging and fire exclusion on ponderosa pine forest structure in the northern Rockies. *Ecological Applications* 20: 1851-64.

[109] Fiedler, C.E., and C.E. Keegan. 2003. Reducing crown fire hazard in fire-adapted forests of New Mexico. Pp. 29-38 in: P.N. Omi and L.A. Joyce (tech. eds.). *Fire, Fuel Treatments, and Ecological Restoration: Conference Proceedings*. 2002 April 16-18: Fort Collins, CO. USDA For. Serv. Rocky Mtn. Res. Sta. Proc. RMRS-P-29. Fort Collins, CO.

[110] Graham, R.T., S. McCaffrey, and T.B. Jain (Tech. Eds.). 2004. *Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-120. Ft. Collins, CO.

[111] Keyes, C.R. and K.L. O'Hara. 2002. Quantifying stand targets for silvicultural prevention of crown fires. *Western Journal of Applied Forestry* 17: 101-09.

low thinning and underburning to reduce surface fuels and increase canopy base height at strategic locations effectively reduces fire hazard at a landscape scale and meets the purpose and need.

**(2) Large tree retention avoids significant cumulative impacts**

Large trees are not abundant at any scale in Southwestern ponderosa pine forest and they are the most difficult of all elements of forest structure to replace once removed.[116] The ecological significance of old growth forest habitat and large trees comprising it is widely recognized.[117]/[118] There is no agreed-upon scientific basis for removing large trees to promote fire resistance in southwestern forests.[119]/[120] In addition to their rarity, a variety of factors other than logging threatens the persistence of the remaining large trees in Southwestern conifer forests. Prescribed fire can injure exposed tree roots that have migrated into accumulated duff layers and cause high levels of post-treatment mortality among large trees.[121] Burning of pine stands with high surface fuel loading also can produce high fireline intensities and result in large tree mortality due to cambial injury by heat.[122] Prescribed fire also may render large trees susceptible to delayed bark beetle infestation.[123] In addition, large tree mortality has indirectly resulted from mechanical thinning activities too.[124] Large standing dead trees ("snags") and downed logs supply critical habitat for primary and secondary cavity-nesting species and may be destroyed by fuel treatments.[125] Prescribed fire may create coarse woody habitat by killing live trees, but gains generally do not offset losses, as existing coarse wood is irretrievably.[126] Recruitment of large trees, snags and large woody debris will become more limiting over time as climate change imposes chronic drought, reduced

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[112] Perry, D.A., H. Jing, A. Youngblood, and D.R. Oetter. 2004. Forest structure and fire susceptibility in volcanic landscapes of the eastern high Cascades, Oregon. *Conservation Biology* 18: 913-26.

[113] Omi and Martinson 2002, Pollett and Omi 2002

[114] Agee, J.K. 1996. The influence of forest structure on fire behavior. Pp. 52-68 in: J.W. Sherlock (chair). *Proc. 17th Forest Vegetation Management Conference.* 1996 Jan. 16-18: Redding, CA. Calif. Dept. Forestry and Fire Protection: Sacramento.

[115] Van Wagner, C.E. 1977. Conditions for the start and spread of crown fire. *Canadian Journal of Forest Research* 7: 23-24.

[116] Agee, J.K. and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211: 83-96.

[117] Friederici, P. (Ed.). 2003. *Ecological Restoration of Southwestern Ponderosa Pine Forests*. Island Press: Washington, DC.

[118] Kaufmann, M.R., W.H. Moir, and W.W. Covington. 1992. Old-growth forests: what do we know about their ecology and management in the Southwest and Rocky Mountain regions? Pp. 1-10 in: M.R. Kaufmann, W.H. Moir, and R.L. Bassett (eds.). *Old-Growth Forests in the Southwest and Rocky Mountain Regions: Proceedings from a Workshop* (1992). Portal, AZ. USDA For. Serv. Gen. Tech. Rep. RM-213. Fort Collins, CO.

[119] Allen, C.D. M.A. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingle. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. *Ecological Applications* 12: 1418-33.

[120] Brown et al. 2004, Dellasala et al. 2004

[121] Sackett, S.S., S.M. Hasse, and M.G. Harrington. 1996. Lessons learned from fire use for restoring Southwestern ponderosa pine ecosystems. In: W.W. Covington and M.R. Wagner (eds.). *Conference on Adaptive Ecosystem Restoration and Management: Restoration of Cordilleran Conifer Landscapes of Northern America*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RM-GTR-278. Fort Collins, CO.

[122] Hunter, M.E., W.D. Shepperd, J.E. Lentile, J.E. Lundquist, M.G. Andreu, J.L. Butler, and F.W. Smith. 2007. *A Comprehensive Guide to Fuels Treatment Practices for Ponderosa Pine in the Black Hills, Colorado Front Range, and Southwest*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-198. Fort Collins, CO.

[123] Wallin, K.F., T.E. Kolb, K.R. Skov, and M.R. Wagner. 2003. Effects of crown scorch on ponderosa pine resistance to bark beetles in northern Arizona. *Environmental Entomology* 32: 652-61.

[124] Hunter et al. 2007

[125] *Ibid*

[126] Randall-Parker, T., and R. Miller. 2002. Effects of prescribed fire in ponderosa pine on key wildlife habitat components: preliminary results and a method for monitoring. Pp. 823-34 in: W.F. Laudenslayer, et al. (coord.). *Proc. Symp. Ecology and Management of Dead Wood in Western Forests*. 1999 November 2-4; Reno, NV. USDA For. Serv. Pac. So. Res. Sta. Gen. Tech. Rep. PSW-GTR-181. Albany, CA.

tree growth rates, and more widespread tree mortality.[127/128/129/130/131] A large tree retention alternative would maintain trees that are most likely to survive fire injury and supply recruitment structure that will support the recovery of old growth forest habitat in the future.

**(3) Large tree retention mitigates adverse effects to wildlife**

Large tree removal reduces forest canopy and diminishes recruitment of large snags and downed logs, which in turn affects long-term forest dynamics, stand development and wildlife habitat suitability.[132/133134] If significant reductions of crown bulk density are deemed necessary to meet the purpose and need then it is highly unlikely that the project will maintain habitat for threatened and sensitive wildlife species associated with closed-canopy forest.[135/136] A large tree retention alternative would maintain wildlife habitat in the short-term and mitigate adverse effects of proposed treatments.

**Old growth**

Old growth forests differ in structure and function from younger forests, providing the preferred habitat of many sensitive wildlife species as well as a host of ecological services including watershed function, water purification, soil retention, and storage of greenhouse gasses.[137/138] Old growth habitat consists of large trees with fire-resistant "plated" bark structure and tall canopies, snags with nesting cavities and broken tops valuable to wildlife, as well as vertical and horizontal structural diversity within stands. As noted above, most of the former old growth forests throughout the ponderosa pine and mixed conifer formations in the Southwest already have been destroyed by logging.

The 1996 Plan Amendment for the Southwestern Region includes mandatory standards and guidelines for old growth habitat management. Each national forest, including the Apache-Sitgreaves National Forest, must allocate no less than 20 percent of each forested "ecosystem management area" to old growth habitat. In order to properly determine old growth habitat, the Forest Service must refer to a specific table included sets forth detailed minimum numeric criteria for various forest types, including the size, age and

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[127] Diggins, C., P.Z. Fulé, J.P. Kaye and W.W. Covington. 2010. Future climate affects management strategies for maintaining forest restoration treatments. *International Journal of Wildland Fire* 19: 903-13.

[128] Savage, M. P.M. Brown, and J. Feddema. 1996. The role of climate in a pine forest regeneration pulse in the southwestern United States. *Ecoscience* 3: 310-18.

[129] Seager, R., M. Ting, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316: 1181-84.

[130] van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fulé, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor and T.T. Veblen. 2009. Widespread increase of tree mortality rates in the western United States. *Science* 323: 521-24.

[131] Williams, A.P., C.D. Allen, C.I Millar, T.W. Swetnam, J. Michaelsen, C.J. Still and S.W. Leavitt. 2010. Forest responses to increasing aridity and warmth in the southwestern United States. *PNAS* 107: 21289-94.

[132] Quigley, T.M., R.W. Haynes and R.T. Graham. 1996. *Disturbance and Forest Health in Oregon and Washington*. USDA For. Serv. Pac. Nor. Res. Sta. Gen. Tech. Rep. PNW-GTR-382. Portland, OR.

[133] Spies, T.A. 2004. Ecological concepts and diversity of old-growth forests. *Journal of Forestry* 102: 14-20.

[134] van Mantgem et al. 2009

[135] Beier, P., and J. Maschinski. 2003. Threatened, endangered, and sensitive species. Pp. 206-327 in: P. Friederici (ed.). *Ecological Restoration of Southwestern Ponderosa Pine Forests*. Island Press: Washington, D.C.

[136] Keyes and O'Hara 2002

[137] Kaufmann et al. 1992

[138] Luyssaert, S., E.D. Schulze, A. Börner, A. Knohl, D. Hessenmöller, B.E. Law, P. Ciais and J. Grace. 2008. Old-growth forests as global carbon sinks. *Nature* 455: 213-15.

number of live and dead trees, down trees and canopy cover. Forested sites must meet or exceed these numeric structural attributes in order to be considered old growth habitat. In addition, the Forest Plan requires the agency to analyze old growth habitat at multiple scales: (1) the ecosystem management area; (2) one scale above the ecosystem management area; and (3) one scale below the ecosystem management area. The amount of old growth that can be provided and maintained must be evaluated at the ecosystem management level and be based on forest type, site capability and disturbance regimes. The Forest Service also must analyze and disclose how many acres within the ecosystem management area currently meet the minimum numeric criteria for old growth habitat set forth in the Forest Plan; assess potential impacts to old growth habitat at the required scales; allocate no less than 20 percent of each management area to old growth as depicted in the Forest Plan; and must not log any of the remaining large trees within the project area until it meets these mandatory requirements.

**Mexican spotted owl**

The effects of mechanical thinning on the MSO have not been extensively studied and are not well understood. Some relevant studies from dry, frequent fire adapted forests of southern California have published findings indicating deleterious effects of thinning of spotted owls. Stephens and colleagues[139] reported that in the Plumas National Forest of California, spotted owl territorial sites declined 43% within 3-4 years of landscape-scale thinning treatments, and following treatment owls redistributed across the landscape. A study by Lee and colleagues[140] reported that in the San Bernardino and San Jacinto of southern California, post-fire salvage logging further reduced California spotted owl occupancy rates beyond the initial impacts of wildfire, leading the authors to recommend that burned stands be monitored for occupancy prior to salvage logging. Elsewhere in the Sierra Nevada, Tempel and colleagues[141] found that, as expected, canopy cover and demographic rates were strongly positively related, and that medium intensity fuels reduction harvest were negatively related to owl reproduction. Other researchers have concluded that thinning effects would be less impactful than severe wildfire,[142] leading to uncertainty of the true impacts of thinning on spotted owls

On April 17, 2009, the Forest Service asked to reinitiate consultation with the FWS regarding continued implementation of forest plans in the Southwestern Region, including the Apache-Sitgreaves Forest Plan. That letter stated, "It has now become apparent that the Forest Service will likely soon exceed the amount of take issued for at least one species, the Mexican spotted owl."[143] More, "[I]t has become apparent that the Forest Service is unable to fully implement and comply with the monitoring requirements associated with the Reasonable and Prudent Measures for several species (including MSO) in the [biological opinion]."

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[139] Scott L. Stephens, Seth W. Bigelow, Ryan D. Burnett, Brandon M. Collins, Claire V. Gallagher, John Keane, Douglas A. Kelt, Malcolm P. North, Lance Jay Roberts, Peter A. Stine, Dirk H. Van Vuren. 2014. California Spotted Owl, Songbird, and Small Mammal Responses to Landscape Fuel Treatments. *BioScience* 64(10): 893-906.

[140] Lee, D.E., M.L. Bond, M. I. Borchert, and R. Turner. 2012. Influence of fire and salvage logging on site occupancy of spotted owls in the San Bernardino and San Jacinto Mountains of southern California. *The Journal of Wildlife Management* 77(7):1327-1341.

[141] Tempel, Douglas J., R.J. Gutierrez, Sheila A. Whitmore, Matthew J. Reetz, Ricka E. Stoelting, William J. Berigan, Mark E. Seamans, and Zachariah Peery. 2014. Effects of forest management on California spotted owls: implications for reducing wildfire in fire-probe forests. *Ecological Applications* 24(8):2089-2106.

[142] Lee, D.C., and L.L. Irwin. 2005. Assessing risks to spotted owls from forest thinning in fire-adapted forests of the western United States. *Forest Ecology and Management* 211:191-209.

[143] Corbin Newman letter to Benjamin Tuggle, April 17, 2009. 2 pages

Monitoring of proposed treatment effects to Mexican spotted owl is of special interest. The Forest Service admitted in the October 2008 Annual Report to FWS, discussed above, and in subsequent litigation that it lacked funding and personnel to conduct required monitoring of owl habitat and populations to ensure that its actions would not jeopardize the continued existence of the species of adversely modify critical habitat. The efficacy of proposed treatments in promoting the conservation and recovery of Mexican spotted owl is uncertain and should be considered a potentially significant effect in the project analysis. The Forest Service should develop and include in the EA a complete monitoring plan, including study design and analysis protocols that are consistent with the region-wide MSO monitoring strategy that resulted from the Centers objection to the 1st 4FRI EIS. This should be made available for public review and comment before a decision is made to implement the project. Based on the criteria developed following the 4FRI objection, the Center has specific questions regarding this requested monitoring plan, including but not limited to: (1) criteria for selection of PAC as paired treatment and control sites; (2) criteria for selection of measurable indicators of change; (3) sampling design power analysis and expected observational error rates; (4) sampling procedures including monitoring cycle; (5) confidence levels to be applied in data analysis and reporting; (6) timeframe for evaluation of results; and (7) triggers for management adaptation using new information.

**Road construction**

The proposed action may include new road construction that may significantly impact soils, water quality, IRA's, WSA's, critical habitats, or other features, and this is a significant issue for environmental analysis if new roads are proposed. Portions of the project area feature steep slopes where new roads and ground-based logging activities may cause significant losses of soil productivity.[144] New roads may permanently impair soil productivity even if their use is temporary.[145] Road-related soil erosion is a chronic source of sediment production that can limit water quality. The distance that sediment travels is an important factor in determining how much eroded soil is delivered to a water body. Soil loss and erosion occurring closer to a stream have greater potential to deliver sediment and lead to water quality impairment than erosion triggered farther away from streams. For this reason, road-stream crossings have high potential to adversely impact water quality.[146] In addition, road construction and fuel treatments may combine to increase overland water flow and runoff by removing vegetation and altering physical and chemical properties of soil, which can permanently alter watershed function.[147/148] This has implications for the purpose and need to protect water quality from socially undesirable effects of flooding and erosion, as well as the need to avoid or minimize project effects to sensitive, candidate and threatened aquatic species. The extent and location of road construction and its effects to soil erosion, runoff channelization and suspended sediment loads merit a hard look in the environmental analysis. This should include

[144] Gucinski, H., M.J. Furniss, R.R. Ziemer and M.H. Brookes (eds.). 2001. *Forest Roads: A Synthesis of Scientific Information.* USDA For. Serv. Gen. Tech. Rep. PNW-GTR-509. Portland, OR.

[145] Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14: 18-30.

[146] Endicott, D. 2008. *National Level Assessment of Water Quality Impairments Related to Forest Roads and Their Prevention by Best Management Practices*. Final report to U.S. Environmental Protection Agency, Contract No. EP-C-05-066, Task Order 002. Great Lakes Environmental Ctr.: Traverse City, MI. December. 259 pp.

[147] Elliot, W.J. 2010. Effects of forest biomass use on watershed processes in the western United States. *Western Journal of Applied Forestry* 25: 12-17.

[148] Robichaud, P.R., L.H. MacDonald and R.B. Foltz. 2010. Fuel management and erosion. Ch. 5 in: W.J. Elliot, I.S. Miller and L. Audin (eds.). *Cumulative Watershed Effects of Fuel Management in the Western United States.* USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-231. Fort Collins, CO.

detailed study (rather than mere mention and cursory dismissal) of an action alternative that foregoes road building on steep slopes and sensitive soils where it may increase erosion or impair productivity.

**Natural Range of Variability for Ponderosa Pine Forests is Broader than Typically Believed**

The Center has considerable concerns with General Technical Report 310.[149] This is the Forest Service's own self-published desired conditions for dry conifer forest in the southwest and its relevance to the East Eagle/Mud Springs Fuels Project should be questioned. Most of the information used in this report to identify desired conditions for ponderosa pine and mixed conifer forest is derived mainly from studies accomplished far from the East Eagle/Mud Springs Fuels Project. We reviewed the 111 studies cited in GTR-310 as sources of information for reference conditions, disturbance histories, disturbance effects, stand structure and composition, and canopy openness. These studies are listed by location in a table and a map on the following pages. Of these 111 published studies, none occurred on the East Eagle/Mud Springs Fuels Project area. As the table later in this letter clearly shows, the sources consulted for the formulation of desired conditions for the southwest cover an extensive geographic range, especially northern Arizona, but provide very little guidance for the unique transitional forests of the southern Apache-Sitgreaves National Forest.

Reynolds and others (p. 12) admit uncertainty in their recommendation of desired conditions for dry conifer forest resulting from a paucity of supporting information and geographic imbalance of accessible data:

"*There is a clear need for additional reference condition data sets, including sites from a wider spectrum across environmental gradients (e.g., soils, moisture, elevations, slopes, aspects) occupied by frequent-fire forests in the Southwest, especially in dry mixed-conifer. While the quantity of reference data sets is increasing, existing data represent a largely unbalanced sampling across gradients (e.g., most data sets are from basaltic soils and on dry to typic plant associations), and there have been few studies quantitatively*."

We request that the Apache-Sitgreaves National Forest will recognize, based on this basic analysis, that the GTR-310 framework is not suited for immediate adoption for meeting ecological needs, formulation of desired conditions, or development of restoration and ecosystem management projects and prescriptions. The GTR-310 approach to uncertainty is to blur site-specific forest variation across a vast geographic area and *scale up* desired conditions to broad landscapes with a generic "pooled natural range of variability" (Reynolds et al. 2103: p. 11):

"*The natural range of variability can be estimated by pooling reference conditions across sites within a forest type. Reference conditions for a forest type typically vary from site to site due to differences in factors such as soil, elevation, slope, aspect, and micro-climate and manifests as differences in fire effects, tree densities, patterns of tree establishment and persistence, and numbers and dispersion of snags and logs. When pooled, these sources of variability comprise the natural range of variability of a site or forest type*."

[149] Reynolds, R.T., A.J. Sánchez Meador, J.A. Youtz, T. Nicolet, M.S. Matonis, P.L. Jackson, D.G. DeLorenzo and A.D. Graves. 2013. *Restoring Composition and Structure in Southwestern Frequent-Fire Forests: A Science-Based Framework for Improving Ecosystem Resiliency*. USDA For. Serv. Rocky Mtn. Res. Sta. Gen. Tech. Rep. RMRS-GTR-310. Fort Collins, CO.

Much of GTR-310 is based on reconstruction studies of "Woolsey Plots." In 1909, T.S. Woolsey, Jr., Assistant District Forester and Chief of the Office of Silviculture (Southwestern District now Southwest Region 3), and G. A. Pearson, Director, Fort Valley Forest Experiment Station (Flagstaff, AZ), drafted instructions that led to establishment of a network of permanent plots in ponderosa pine, mixed conifer, and spruce-fir forests of the Southwest. Between 1909 and 1941 Woolsey and team established 140 plots in AZ and NM, of which 98 were in ponderosa pine. Of the pine plots, 30% are located southwest of Flagstaff at the Coulter Ranch site. Of the 140 plots, 44 were in the Coconino NF.

"*So-called sample plots were established on logged over areas in order to ascertain how fast residual stands would grow, whether they could produce merchantable timber, and whether natural restocking would take place*" (Pearson, 1933, p. 272).

Bell and others[150] compared current conditions of 14 Woolsey plots to 98 AZCFI and 58 FSFIA plots in the Flagstaff/western Mogollon Rim area. The metrics under comparison were Trees/Hectare, BA/Hectare, QMD, and frequency of DBH classes/hectare. Comparisons of forest structural data applied a distance-based multivariate nonparametric permutation method. All analyses indicated dissimilarity between the FIA and CFI plots compared to the Woolsey plots across the study area, and across TEU's. Within TEU's, the Woolsey plots were not statistically dissimilar, but current conditions were consistently denser in all metrics. Results suggest that Woolsey plots are only representative of the TEU to which the plot belongs.

"*The selection of [Woolsey] plot locations in the early 1900s followed a subjective nonrandom approach. [Our] results indicated that the Woolsey plots (1) were neither historically nor contemporarily representative of the entire study area because of environmental and current forest structural differences with respect to the FSFIA and AZCFI and (2) may be considered historically representative of their corresponding TEUs. Our study supports the use of TEUs for defining the applicability of information obtained from the Woolsey plots….Subjective plot selection, together with the small sample size of this rare dataset, raises questions about the inference space with regard to the larger, heterogeneous landscape of ponderosa pine forests in northern Arizona*"

Disturbance patterns are driven by spatial and temporal variation in climate, vegetation growth habitats, and management history. These are place-specific and cannot reliably be generalized over broad landscapes or timeframes.[151/152] Ecologists stress definition of locally specific reference conditions to justify restoration goals and outcomes due to scale dependence of ecological pattern.[153/154/155] For

[150] Bell, D.M., P.F. Parysow, and M.M. Moore. 2009. Assessing the representativeness of the oldest permanent inventory plots in northern Arizona ponderosa pine forests. *Restoration Ecology* 17(3): 369-377.

[151] Agee, J.K. 1996. The influence of forest structure on fire behavior. Pp. 52-68 in: J.W. Sherlock (chair). *Proc. 17th Forest Vegetation Management Conference.* 1996 Jan. 16-18: Redding, CA. Calif. Dept. Forestry and Fire Protection: Sacramento.

[152] DellaSala, D.A., J.E. Williams, C.D. Williams and J.F. Franklin. 2004. Beyond smoke and mirrors: a synthesis of fire policy and science. *Conservation Biology* 18: 976-86.

[153] Noss, R., P. Beier, W. W. Covington, R. E. Grumbine, D. B. Lindenmayer, J. W. Prather, F. Schmiegelow, T. D. Sisk, and D. J. Vosick. 2006. Recommendations for integrating restoration ecology and conservation biology in ponderosa pine forests of the Southwestern United States. *Restoration Ecology* 14: 4-10.

[154] Swetnam, T.W., C.D. Allen and J.L. Betancourt. 1999. Applied historical ecology: Using the past to manage the future. *Ecological Applications* 9(4):1189-1206.

[155] White, P.S. and J.L. Walker. 1997. Approximating nature's variation: selecting and using reference information in restoration ecology. *Restoration Ecology* 5: 338-349.

example, Korb and others[156] stated this about their study results from the San Juan Mountains of southern Colorado:

"*Our findings demonstrate the need to develop site-specific reference conditions and for managers to exercise caution when extrapolating fire regimes and forest structure from one geographic locality to another given a projected warmer climate making conditions more favorable to frequent, large wildfires*."

Desired conditions for dry conifer forests suggested by Reynolds and others (2013) are clearly not specific to the southern portion of the Apache-Sitgreaves National Forest, and should be critically reviewed prior to assuming their usefulness. They fail to address uncertainty and qualified disagreement among experts about forest ecology and management in the Southwestern Region. Close inspection of place-specific information reveals that Reynolds and others selectively interpreted literature to make a poorly supported case for sustained mechanical intervention as a surrogate for restoration of natural fire regimes. Reynolds and others (p. 48-49) state:

"*The re-establishment of frequent, low-severity fire is critical to the success of our restoration framework. However, because of limitations such as proximity to human developments, air quality restrictions, and workforce capacity, the use of fire will probably continue to be limited. Therefore, mechanical-only treatments, or perhaps combinations of fire and mechanical treatments, are likely to be the restoration tools of choice in much of the Southwestern landscape*."

That statement is the sole basis presented by the authors for their recommendation of landscape-scale mechanical treatments of vegetation in ponderosa pine and mixed conifer forest. Furthermore, we would argue that workforce limitations will affect mechanical thinning operations more than fire management crews. The "implementation recommendations" of Reynolds and others (p. 35-37) do not present a compelling fact-based case for the efficacy of mechanical treatments to manage structure or composition in fire-adapted forest, other than to allude that such treatments may be desirable for unstated reasons.

It is true that Reynolds and colleagues synthesized a wide array of literature, but, the studies used to substantiate the GTR-310 structural framework are disproportionately clustered around northern Arizona, including a number of studies at the same sites (Gus Pearson Natural Area and Fort Valley Experimental Forest), and including a reliance on re-measures of the historic "Woolsey plots", which are not representative of the surrounding landscape[157]. Furthermore, some suitable reference sites were notably excluded from GTR-310, such as the Long Valley Experimental Forest, which was established in 1936 as a comparison site to the much-studied Fort Valley unit. Long Valley "*contained some of the best stands of ponderosa pine on the Coconino and Sitgreaves National Forests*[158]", but for an unknown reason it does not appear in GTR-310.

The regional desired conditions document does mention this site (DC's, p. 14), noting that "*On the Long Valley Experimental Forest (sedimentary soils on the Mogollon Rim, central Arizona), the sampled trees per acre (1938) ranged up to 99 trees per acre, with an estimated 75 trees per acre being present prior to*

[156] Korb, J.E., P.Z. Fule, P.Z. and R. Wu. 2013. Variability of warm/dry mixed conifer forests in southwestern Colorado, USA: Implications for ecological restoration. *Forest Ecology and Management* 304:182-191.
[157] The reconstructions by ERI scientists on Woolsey plots have established a high bar for scientific integrity, but the plots were subjectively located by Woolsey and team as part of early silvicultural experiments, calling the usefulness of the results to be interpreted carefully and within a broader collection of multiple lines of evidence on representative sites.
[158] https://www.fs.usda.gov/main/longvalley/home

*the cessation of frequent fire (circa 1880-1900, USDA Forest Service, unpublished data from Long Valley Experimental Forest).*" If the pre-settlement trees per acre value (~75TPA) was included in GTR-310, it would have been more dense than any other ponderosa pine reference site cited in Arizona, with the exception of the four Grand Canyon sites studied by Fule et al. (2002[159]; based on ranges provided in GTR-310), and would have been essentially equal to Williams and Bakers studies along the Mogollon Rim which have been widely criticized by the restoration community[160]. The only site cited in GTR-310 that Long Valley would have been less dense than is Malay Gap, studied by Cooper (1960[161]), and this site was in fact not even as dense as Coopers Maverick study site that was not included in GTR-310. Also, Long Valley may have been even denser, assuming that not all of the remaining 24 post-fire suppression trees would have been killed by fire.

Cooper studied three sites on the White Mountain and San Carlos Apache Reservations in 1957. His paper is one of the most oft-cited sources of reference conditions data and descriptions for southwestern ponderosa pine, including by Reynolds et al (2014), and it is of particularly high importance for the East Eagle-Mud Springs Fuels Project. His Bog Creek site was selectively logged in the 1930's, but his Maverick and Malay Gap sites were unlogged, the latter also having never experienced fire suppression nor livestock grazing. Of the Malay Gap site, Cooper (p. 139) wrote "*this is perhaps the closest approach to a truly primeval forest left in the Southwest*." Prior to 1910, the Malay Gap site had experienced wildfire on average every 7 years, and then burnt again in 1910, 1919, 1935, and lastly in 1943. By the time of his field work, in 1957, the fire regime was effectively uninterrupted. Cooper's extensive report is indeed one of the most essential studies to read and comprehend, and it is important to fully examine the breadth and depth of his analyses, as well as the photographs included therein, in order to responsibly reference this detailed work. It is a step backwards for restoration ecologists to dilute his work to a few numbers, such as his determination that mean basal area at Malay Gap, where a visitor "*is immediately struck by the open nature of the forest*", was 70 $ft^2$/acre[162] (photo next page). The figure below, taken directly from Cooper (1960: p. 150), shows an image that does not support most contemporary notions of an "open" forest, and in fact might be considered overly dense by many land managers.

[159] Fulé, P.Z., W.W. Covington, M.M. Moore, T.A. Heinlein, and A.E.M. Waltz. 2002. Natural variability in forests of the Grand Canyon, USA. *Journal of Biogeography* 29:31-47.

[160] See Fule et al., 2014. "Unsupported inferences of high-severity fire in historical dry forests of the western United States: a response to Williams and Baker." *Global Ecology and Biogeography* 23:825-830.

[161] Cooper, C.F. 1960. Changes in vegetation, structure and growth of southwestern pine forests since white settlement. *Ecological Monographs* 30: 129-64.

[162] Interestingly, Reynolds et al. (2013) cite Malay Gap as a reference site, but ignore the results from the Maverick study location, which had a mean basal area of 102 $ft^2$/acre, to which Cooper (1960: p. 150) remarked: *"Although similar in basic composition and structure, the forests at Maverick and Malay Gap are quite different in appearance… The site at Malay Gap is clearly not as good as that at Maverick. The average height of mature dominants at Malay Gap is 95 ft, while those at Maverick average about 110 ft…The difference reflects inherent differences in site productivity*." The basal area of old growth at Maverick exceeds the range reported in Reynolds et al. (2013) and is outside of the basal area range given in Table 2 in the regional desired conditions document.

FOREST CONDITIONS AT MAVERICK AND AT MALAY GAP

Although similar in basic composition and structure, the forests at Maverick and at Malay Gap are quite different in appearance. A visitor to Malay Gap, conditioned by acquaintance with the over-dense thickets characteristic of most of the Southwestern pine region, is immediately struck by the open nature of the forest (Fig. 20). The forest floor is carpeted with a deep layer of grass, and small discrete patches of young trees are dispersed among groups of stately pines. The pure beauty of the Malay Gap region more than compensates for its difficulty of access.

FIG. 20. Typical view of the ponderosa pine forest in the primitive area at Malay Gap.

In addition to simple density metrics, Cooper reported on spatial arrangement, age/size distributions, regeneration patterns in time and space, fire effects on stand development, and many other important ecological processes that are still being debated. Of particular relevance to the current debate in ponderosa pine restoration are his observations on the grouping habits of this species.

The figure on the next page (Cooper, 1960: p. 148) is a typical example of the "*conspicuous… grouped arrangement of the trees*." Similarly to the figure provided on the previous page, this image again contradicts the widespread contemporary notion of what constitutes a "*distinct group*". Nowhere in his report does Cooper specify how he determined what a "group" was, but it would seem apparent that his definition is markedly different than many offered today.

The concept of "interspaces" is a central tenet in the formulation of desired conditions by some within the U.S. Forest Service, wherein these "interspaces" are areas not occupied by trees and serve to define somewhat even-aged groups. The entire basis of the model promulgated in Reynolds and others is built around this notion. However, Cooper's analysis of Malay Gap might suggest that this model is not applicable to all areas. In discussing structural patterns in the virgin pine forest, he remarked (at p. 158):

PATTERN

A conspicuous feature of the ponderosa pine forest is the grouped arrangement of the trees. It is obvious that the forest is composed of distinct groups, each made up of several trees similar in size and apparent age (Fig. 17). This fact has long been recognized, but surprisingly little attention has been given to the structure of these groups or to their mode of origin.

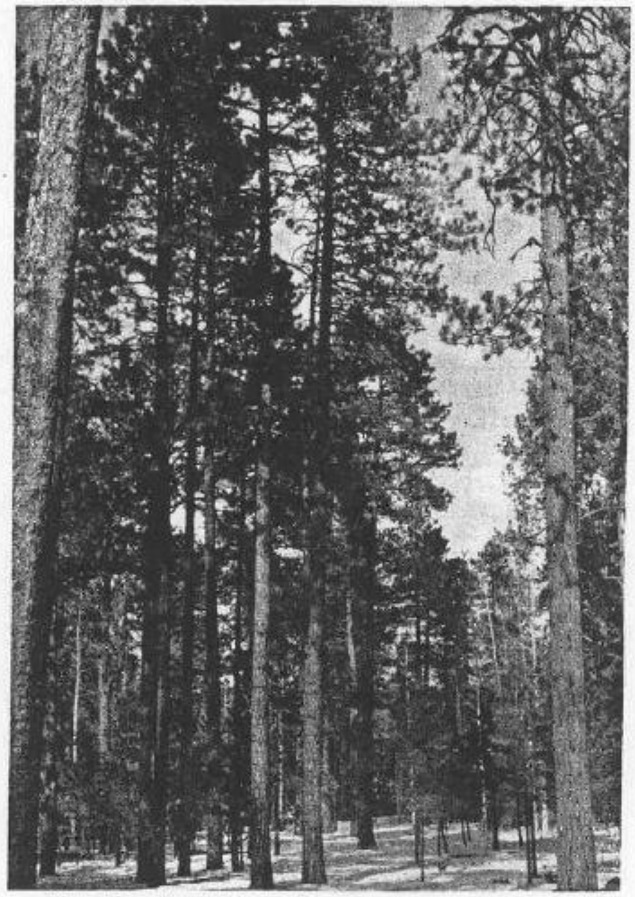


FIG. 17. Typical stand of mature ponderosa pine, showing grouped distribution of trees.

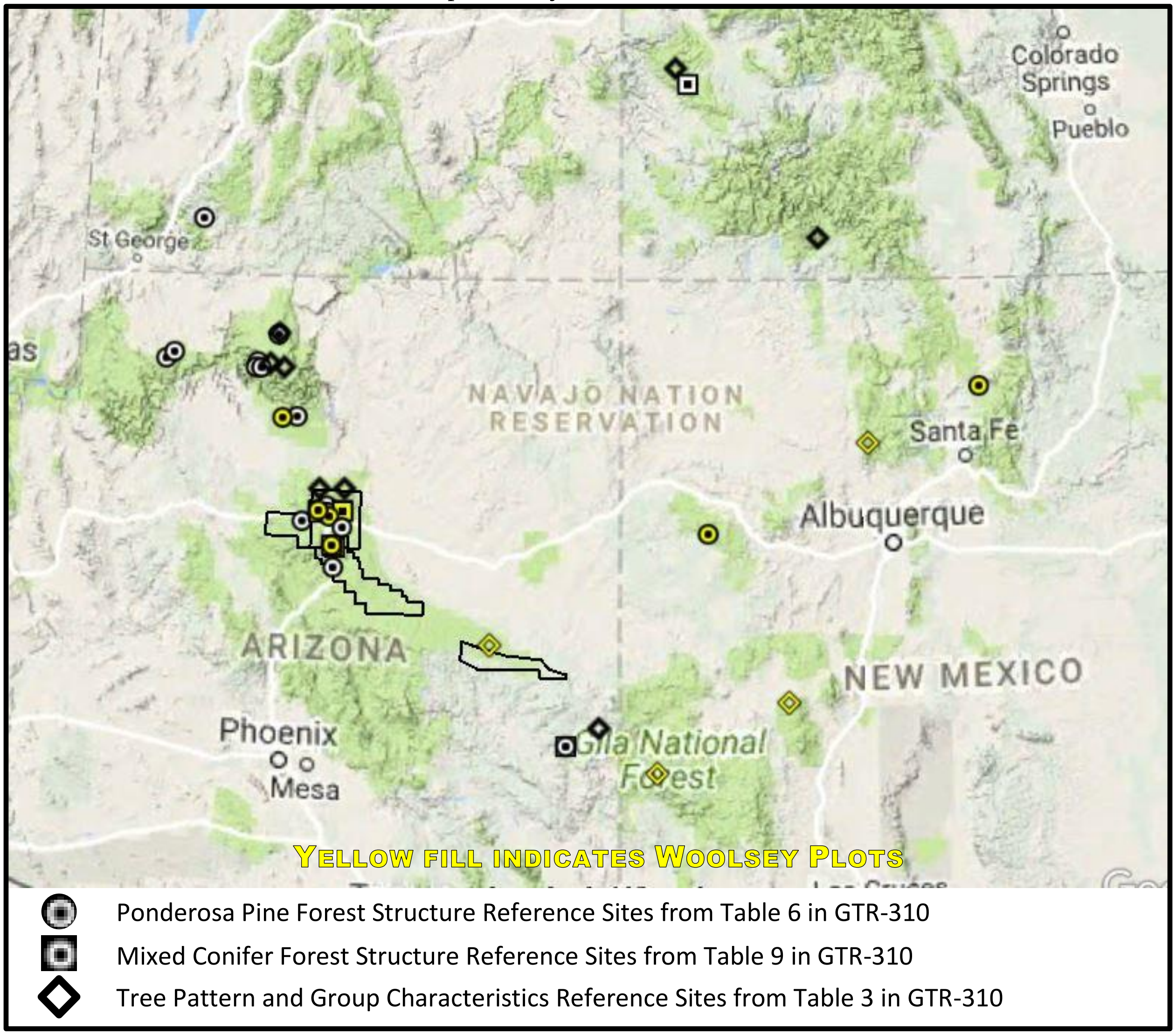
"*The relatively small size of the even-aged groups in the southwestern forest is due to the small size of the openings in which the groups can become established*."[163]

If the East Eagle-Mud Springs Fuels Project is to base its desired conditions on GTR-310, then the project is lacking some significant guidance provided by these other neglected reference sites. Additionally, it's critical to remember that almost no scientific attention has been given to determining reference conditions in the forests of the East Eagle-Mud Springs Fuels Project landscape. The East Eagle-Mud Springs Fuels Project.is not proceeding under the direction of good science without seeking to better understand reference conditions in the unique forests and woodlands of this landscape.

[163] Cooper's report does not specifically provide data as to how many trees occur per group, but he does state (at p. 149) that "*analysis indicates that the mature stands at both Maverick and Malay Gap are aggregated into groups with an area of .16 to .32* [acres]", within the range described by Reynolds et al. (2013). However, the definition of a "group" would seem to differ greatly between the two sources based on comparison of Cooper's example photos and observations at the Bluewater demonstration site and other contemporary treatments.

**<u>Locations Of Certain Reference Sites* Used In GTR-310</u>** <u>(Reynolds et al., 2013)</u>

*Specifically Tables 3, 6 and 9




Sites referenced by Reynolds et al (2013) are biased towards conditions at the Grand Canyon and Mogollon Plateau around Flagstaff. All sites shown for New Mexico are limited to original inventory by Woolsey (1909-1913) and subsequent re-measures of those sites (Moore et al. 2004). Polygons represent work by Abella and Denton (2009; square around Flagstaff) and Williams and Baker (2012; two polygons along Mogollon Rim). None of the studies assessed in GTR-310 include sites with ponderosa pine-evergreen oak or ponderosa pine-shrub types.

"*The minimum diameters reported in Table 6 may also result in a source of error that can lead to small underestimates of historical tree densities reported in studies. Additional error may result from missing fully decomposed structures at time of measurement and reconstruction*" (Reynolds et al., 2013: p.17).

"*To date, only six studies report tree spatial reference conditions in the Southwestern ponderosa pine forests*" (Reynolds et al., 2013: p.17). "*Management informed by reference conditions and natural ranges of variability (the range of ecological and evolutionary conditions **appropriate for an area**) allow for the restoration of the characteristic composition, structure, spatial pattern, processes, and functions of ecosystems*" (Reynolds et al., 2013: p.2, emphasis added).

**Figure 2: Locations Of Studies Cited In Reynolds et el. (2013)**
*see GTR-310 for full citations

| **General Location of Referenced Literature** | **Literature cited for that location in GTR-310**<br>**Bold** denotes measurements at historic Woolsey plots<br><u>Underline</u> denotes study specific to Gus Pearson Natural Area, Coconino NF |
|---|---|
| New Mexico | **Moore et al., 1994 (Gila & Zuni Mtns Woolsey remeasures); Woolsey, 1911 (Carson, Zuni, Gila, Alamo, Jemez sites);** Allen, 2007 (northern NM); Brown et al., 2001 (Sacramento Mountains); Conklin & Geils, 2008 (Jemez & Manzano Mountains); Kaye & Swetnam, 1999 (Sacramento Mountains); Negron, 1997 (Sacramento Mountains); Romme et al., 1999 (Carson & Santa Fe NF's); Swetnam & Dieterich, 1985 (Gila Wilderness); Touchan et al., 1996 (Jemez Mountains) |
| North Rim Grand Canyon/Kaibab Plateau/Uinkaret Plateau | Covington & Moore, 1994; Fule et al., 2002; Fule et al., 2003; Fule & Laughlin, 2007; Heinlein et al., 1999; Lang & Stewart, 1910; Rasmussen, 1941; Roccaforte et al., 2010; Waltz & Fule, 1998; White & Vankat, 1993 |
| South Rim Grand Canyon | Fule et al., 2002; Harrington & Hawksworth, 1980; **Woolsey, 1911** |
| Mogollon Plateau (Flagstaff Area) | Abella & Denton, 2009; Abella et al., 2011; <u>Biondi et al., 1994; Biondi, 1996;</u> Cocke et al., 2005; <u>Covington & Sacket, 1986;</u> Covington & Moore, 1994a&b; <u>Covington et al., 1997</u>; Dieterich, 1980; Fule et al., 1997; Heinlein et al., 2005; Hoffman et al., 2007; <u>Mast et al., 1999;</u> Menzel & Covington, 1997; <u>Pearson, 1950; White, 1985;</u> **Sanchez Meador et al., 2011; Sanchez Meador & Moore, 2010; Woolsey, 1911;** Schneider, 2012; Williams & Baker, 2012 |
| Mogollon Rim (Apache-Sitgreaves NF, White Mtn. Apache Reservation) | Cooper, 1960, 1961; Greenamyre, 1913; Lynch et al., 2010; Williams & Baker, 2012; **Woolsey, 1911** |
| Colorado | Binkley et al., 2008 (Uncompahgre Plateau); Boyden et al., 2005 (Front Range); Brown & Wu, 2005 (SW of Pagosa Springs); Ehle & Baker, 2003 (RMNP); Fornwalt et al., 2002 (Front Range); Fule et al., 2009 (San Juan Mountains); Grissino-Mayer et al., 2004 (San Juan Mountains); Korb et al., 2012 (San Juan Mountains); Mast et al., 1998 (Front Range); Mast & Veblen, 1999 (Front Range); Romme et al., 1999 (SW Colorado) |
| Southwestern Utah | Madany & West (Zion National Park) |
| Pacific and Inland Northwest/Northern Rocky Mountains/Black Hills (South Dakota) | Agee, 2003; Arno et al., 1995; DeLuca & Sala, 2006; Franklin et al., 2002 (incorrectly cited as 2012); Harrod et al., 1999; Hessberg et al., 1994, 2004, 2005; Lundquist, 1995; Nacify et al., 2010; Taylor, 2010; Taylor & Skinner, 2003; Von Schrenck, 1903; West, 1969; Wickman, 1963; Youngblood et al., 2004 |
| Mexico/Baja California | Minnisch et al., 2000; Stephens et al., 2008 |
| California | Fettig, 2012; Parsons & DeBenedetti, 1979 (Sequoia & Kings Canyon NP); Scholl & Taylor, 2010 (Yosemite NP) |
| Sky Islands Region | Barton, 2002; Grissino-Mayer et al., 1995 |
| Illinois | Dhillon & Anderson, 1993 |
| Macro-scale studies (west-wide/regional) | Bentz et al., 2010; Drummond, 1982; Littell et al., 2009; Maffei & Beatty, 1988; Moeck et al., 1981; Negron et al., 2009; Swetnam & Baison, 1996*; Savage & Mast, 2005*; Swetnam & Betancourt, 1990*; Wood, 1983 |
| Review Reports, books, or general literature inappropriately cited as reference-site studies or original research | Abella, 2008; Abella, 2009; Castello et al., 1995; Edmunds et al., 2000; Ferry et al., 1995; Fitzgerald, 2005; Friederici, 2004; Goheen & Hansen, 1993; Hart et al., 2005; Hawksworth & Weins, 1996; Jenkins et al., 2008; Larson & Churchill, 2012; Miller & Keen, 1960; Miller, 2000; Rippy et al., 2005; Smith, 2006a,b,c; Stevens & Hawksworth, 1984; Tainter & Baker, 1996; Weaver, 1950 |

**Summary**

1) The East Eagle/Mud Springs Fuels Project should follow a process-centered restoration approach whereby restoration of natural fire and disturbance processes are given priority over purely structural considerations, considering that Regional direction in GTR-310 is not easily applicable to the project area, and that intensive management for mistletoe reduction is not consistent with ecological restoration principles or forest stakeholder interests.

2) The Project should strategically place limited mechanical fuels reduction treatments in priority areas (especially the WUI) to enable expanded use of prescribed and natural fires to achieve desired conditions while protecting resource values, critical infrastructure, and WUI. We are attaching the recently proposed Strategic Treatments for Fire Use Alternative that we prepared for the 4FRI Rim Country analysis, which will provide an example of the rationale and potential direction for such an optimized approach.

3) The Project should protect and retain trees over 16" diameter in accordance with the 4FRI large tree retention strategy and the 4FRI SPLYT (Stands with a Preponderance of Large Young Trees) protocol (both attached), because that will:

- A) Meet the Project's purpose and need;
- B) Avoid significant cumulative impacts;
- C) Mitigate adverse effects to wildlife;
- (D) Move towards desired conditions sooner;
- (E) Be consistent with neighboring projects, including not only 4FRI but the West Escudilla Restoration Project.

4) Under the current Forest Plan direction, the Project must analyze old growth forest area and manage no less than 20% of each management area as old growth.

5) Develop a monitoring plan for assessing treatment impacts to Mexican spotted owl consistent with the 4FRI objection resolution (attached), avoid road construction in PACs and minimize road construction in the general landscape, apply specific fuel treatment modeling approaches in MSO habitat, and implement existing Forest Plan standards and guidelines without amendment.

The following documents are attached to this letter to help inform the planning process:

Item A. Cooper's (1960) seminal report on old growth ponderosa pine forest

Item B. 4FRI Old and Large Tree Retention

Item C. The most recent "SPLYT" agreement, which is the stakeholder-developed and consensus-based direction for identifying Stands with a Preponderance of Large Young Trees, a category addressed in the 4FRI Old and Large Tree Retention Strategy.

Item D. The Centers Objection Letter to the West Escudilla Restoration Project. Therein, we requested that the project incorporate the aforementioned Strategy and most-recent SPLYT definitions, as well as 4FRI stakeholder-developed treatment approaches for stands with occurrence of southwestern dwarf mistletoe

Item E. The Deputy Regional Foresters Resolution Letter regarding the Centers Objection to the West Escudilla Restoration Project, wherein the Deputy Regional Forester and Apache-Sitgreaves Supervisor agreed to incorporate the Centers concerns in exchange for our agreement to withdraw the Objection.

Item F. A 4FRI stakeholder's letter addressing the unanimous rejection of the Forest Service's proposals to utilize aggressive overstory removal and even-aged management approaches in treating stands infected with mistletoe.

Item G. 4FRI Objection Response letter from Regional Forester Cal Joyner to Jay Lininger of the Center, specifically CBD Issue 5 on pages 15-17, resolving the monitoring and implementation of combined treatments in MSO PACs.

Item H. 4FRI Strategic Treatments for Fire Use Alternative, prepared by the Center for the 4FRI Rim Country Analysis.

We appreciate the opportunity to engage in this important project with the Apache-Sitgreaves National Forest. Please keep me updated with project developments, opportunities to comment and collaborate, and any other time-sensitive notifications.

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ITEM A:

Cooper's (1960) seminal report on old growth ponderosa pine forest

# CHANGES IN VEGETATION, STRUCTURE, AND GROWTH OF SOUTHWESTERN PINE FORESTS SINCE WHITE SETTLEMENT

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## INTRODUCTION

More than a century ago, Lt. Edward Beale wrote of northern Arizona: "It is the most beautiful region I ever remember to have seen in any part of the world. A vast forest of gigantic pines, intersected frequently with open glades, sprinkled all over with mountains, meadows, and wide savannahs, and covered with the richest grasses, was traversed by our party for many days." (quoted by Bell, 1870). There are those today who would agree with the lieutenant's conclusions, but the northern Arizona countryside is no longer the same land that Beale saw in 1857. Eighty-five years of white man's use and occupancy have profoundly altered the forest landscape. Northern Arizona is particularly suitable for a study of the dynamics of vegetation change under the influence of the white man and his use of the land. Here these changes have taken place within the lifetime of men still living, and are easier to trace than in longer-settled regions.

As in Beale's day, an almost unbroken band of ponderosa pine forest 25 to 40 mi wide and nearly 300 mi long spreads across central and northern Arizona. With outliers in the higher mountains throughout the state, it constitutes one of the largest pine forests in North America. Of the more than 3,000,000 A of commercial forest land in Arizona, by far the largest part supports a nearly pure stand of ponderosa pine (*Pinus ponderosa*). (The botanical nomenclature of Kearney & Peebles (1951) is followed throughout.) The pine zone occupies most of the mountain and plateau country above about 6,500 ft. On the higher peaks, above about 8,500 ft, the pine is largely replaced by a mixed forest of Douglas fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and other species. Below the pine forest lies a pinon-juniper woodland.

This study of vegetation change was approached on the one hand from the historical viewpoint. Due to the late settlement of the region, Arizona is almost unique in the United States in that reasonably well-planned scientific exploration preceded extensive exploitation. Many early travellers left records of their impressions of the pine forest country. Individually, these early reports are of little value in reconstructing the vegetation of the past century. Cumulatively, however, they build up a fairly clear picture.

The second approach was analysis of stand structure. The present mature forest, with an overstory of trees aged 150 yrs and more, obviously originated before white settlement. The structure of the mature forest was studied and compared with that of the young forest that will comprise the overstory of the future.

This study was made possible by a National

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Science Foundation Predoctoral Fellowship for the academic years 1956-57 and 1957-58. Field work was supported in part by National Science Foundation Research Grant G-3834. Thanks are due to the Tribal Councils of the San Carlos and White Mountain Apache Tribes for permission to carry out the field work on their tribal lands, and to Superintendent Albert Hawley and his staff at the Fort Apache Agency, Whiteriver, Arizona, for assistance. Much useful information was provided by Paul Buss, Forest Manager, San Carlos Indian Reservation, and LaVon Dunford, Forest Engineer, Southwest Lumber Mills, Inc. Among those who assisted with advice and criticism were R. R. Humphrey and C. W. Ferguson of the University of Arizona, J. E. Fletcher of Agricultural Research Service, and F. X. Schumacher of Duke University. Mrs. Lutie Higley, reference librarian at the University of Arizona Library, was unfailingly helpful in the historical phases of the study. Finally, I wish to acknowledge my special debt to Dr. H. J. Oosting of the Department of Botany, Duke University, and to Mr. Harry Kallander, Forest Manager, Fort Apache Indian Reservation.

## THE HISTORICAL EVIDENCE

". . . the first dayes we founde no grasse, but worser way of mountaines and badde passages, then we had passed alreadie: and the horses being tired, were greatly molested therewith." In those unflattering terms the first white man to leave a permanent record described his visit to the White Mountains (Letter, Coronado to Mendoza, August 3, 1540. Translated in Hakluyt, 1600:375). Francisco Vasquez Coronado forded the Gila River somewhere below the present town of Safford, and crossed the White Mountains to the Indian town of Zuni. Thus began some three centuries of sporadic visits to the northern Arizona mountains by Spanish adventurers, missionaries, and would-be colonists. The mountain region was occupied by nomadic food-gathering Indians, mostly Apaches and their close relatives, the Navajos. The Spanish conquistadores found that these people could not be conquered by the means then available to Spain, they would not stay converted, and they had no property worth stealing (Webb, 1931). So, "Nearly all of what we now call Arizona has no other history before 1846 than the record of exploring entradas from the south and east" (Bancroft, 1889). A relatively few Apaches, masters of guerilla warfare, were able to prevent white settlement and to hold the country for themselves for more than 300 yrs.

The Treaty of Guadalupe Hidalgo transferred Arizona and New Mexico to American jurisdiction in 1848. Thereafter, the Apaches were an American problem for nearly 40 yrs. Sporadic and confused attempts at control were ended by the Civil War. After the war, serious efforts to subdue the Apaches got under way. More or less permanent peace came to the north and west in 1874, and the northern pine country was open to settlement and exploitation by white men.

### ORIGINAL CONDITION OF THE PINE FOREST

"We came to a glorious forest of lofty pines, through which we have travelled ten miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with the pine regions, it was not so in this instance; every foot being covered with the finest grass, and beautiful broad grassy vales extending in every direction. The forest was perfectly open and unencumbered with brush wood, so that the travelling was excellent." (Beale, 1858). The overwhelming impression that one gets from the older Indians and white pioneers of the Arizona pine region is that the entire forest was once much more open and park-like than it is today. A critical examination of early reports of travellers in northern Arizona at the time of white settlement may shed some light on primeval forest conditions, and on changes in those conditions within historic times.

There are no reliable reports from the northern mountains until after 1848. The first official expedition, under Capt. Lorenzo Sitgreaves, missed most of the forest area. Lt. Whipple in 1853 led a party surveying a possible route for a transcontinental railroad along the 35th parallel. Lt. Beale, commanding the famous band of camels that was expected to revolutionize transportation in the Southwest, crossed the area in 1857 and again in the winter of 1858-59. Lt. Ives explored the Colorado River and led the first expedition into the Grand Canyon country. After the Civil War the number of military and civilian visitors increased rapidly. The period of exploration culminated with the expeditions of the Wheeler Survey, predecessor of the present U. S. Geological Survey, in the years 1871-1875. Accompanying virtually all these early expeditions was a naturalist whose duty it was to describe the country for the benefit of prospective settlers and to collect information on the botany, zoology, and geology of the region.

Most of the early travellers were impressed by the open nature of the forest. Ives (1861) described the region at the base of Bill Williams Mountain: "This morning we re-entered the region of pines, and have travelled all day in the midst of picturesque and charming scenery. The valleys are covered with a bright green sward, and open groves are dispersed gracefully upon the lowlands and ridges." Joseph Rothrock (1875), botanist with the Wheeler Survey, wrote of the region just south of Gallup, New Mexico: "Gaining the summit a thousand feet above Fort Wingate, we were at an altitude of about 8000 feet above the sea, a fine, open, park-like region with a large growth of yellow pine (*Pinus ponderosa*) and fir covering the hillsides. A diversified herbaceous vegetation was out in the most brilliant colors, beautifying alike the woods and open grounds. . . . Good forage was abundant." This area today is almost bare of herbaceous ground cover, and dense thickets of pine saplings predominate.

The glowing reports of Lt. Beale have already been quoted. Whipple (1856) was more restrained in his comments, but he too remarks on the open nature of the pine forest. C. Hart Merriam (1890) based his life zone concept largely on a study of vertical zonation of vegetation on the San Francisco Mountains. In describing his study area he said, "The lava plateau above about 2130 meters (7000 feet) is covered throughout with a beautiful forest of stately pines (*Pinus ponderosa*) which average at least 33 meters (100 feet) in height. There is no undergrowth to obstruct the view, and after the rainy season the grass beneath the trees is knee-deep in places, but the growth is sparse on account of the rocky nature of the surface." Dutton's classic "Physical Geology of the Grand Cañon Region" (1887) says of the Kaibab Plateau: "The trees are large and noble in aspect and stand widely apart, except in the highest part of the plateau where spruces predominate. Instead of dense thickets where we are shut in by impenetrable foliage, we can look far beyond and see the tree trunks vanishing away like an infinite colonade. The ground is unobstructed and inviting. There is a constant succession of parks and glades—dreamy avenues of grass and flowers winding between sylvan walls, or spreading out in broad open meadows. From June until September there is a display of wild flowers which is quite beyond description."

Although the early chroniclers were almost unanimous in their description of an open forest, it is evident that some reproduction did exist. Beadle (1873) reported that on the Defiance Plateau, "The tall sugar pines [*sic*] from three inches to two feet in diameter, mingled with a few dwarfish oaks, were scattered in regular proportion." In a report on the Gila River Forest Reserve, Rixon (1905) stated, "The south side of Spring Creek is covered with a phenomenal growth of young pine, approximating 30 feet in height and 6 inches in diameter." In his township by township description of the Reserve, he referred to abundant growth of young pines in some areas, while elsewhere it is not mentioned or is remarked as absent. Plummer (1904), in a similar examination of the Black Mesa Forest Reserve, found exceptionally heavy stands of young trees in some places. Lieberg *et al.* (1904) were struck by the lack of reproduction on the San Francisco Mountain Forest Reserve: "Apparently there has been an almost complete cessation of reproduction over very large areas during the past twenty or twenty-five years, and there is no evidence that previous to that time it was at any period very exuberant." Pearson (1910) early in his career noted that reproduction was generally deficient both in the virgin forest and after logging. He noted, however, that reproduction on the Prescott National Forest was good and in places so dense it was difficult to walk through.

The early explorers were particularly conscious of grass, upon which they depended to feed their horses. Both Whipple (1856) and Beale (1858) commented about the abundance of grass in the forested area, but both observed that grass was more plentiful on lava soils than on heavier soils derived from sedimentary rocks. Lt. George Wheeler in 1873 was the first white man to climb Mt. Baldy (Mt. Thomas), the highest peak in the White Mountains. He reported that ". . . a plateau bearing patches of bunch grass is reached. . . . The animals feast upon the rank and succulent mountain bunch grass." (Wheeler, 1878). This would imply that good grass was not universal in the mountains at that time. The same conclusion can be drawn from the reports of Coronado's journey more than three centuries earlier. Coronado (Winship, 1899) spoke feelingly of the difficulty of crossing the White Mountains, and of the good grass at Zuni, "of which we had great need, because our horses were so weak and feeble when they arrived."

Rothrock (1878) described a dense grass cover in the pine zone of southern Colorado: "In the beautiful valley of the Conejos River, after striking the timbered region, we found luxuriant bunch-grass covering the ground as thickly as it could stand. In November it was still green about the roots, and was eagerly eaten by our starved mules. *Pinus ponderosa* formed open clumps, and under protection of these trees it attained what seemed to be its maximum growth." Nelson (1884), a zoologist collecting for the Smithsonian Institution, said of the region above Springerville: "There is scarcely any undergrowth, but a dense mat of grass and flowers in these forests, and beautiful mountain parks are found at frequent intervals."

In the University of Arizona Library is a collection of reports on range conditions in the first decade of this century. Although these reports bear no signature, there can be little doubt that they were written by Dr. J. J. Thornber, Botanist at the Arizona Agricultural Experiment Station. In July, 1905, he travelled by wagon from San Carlos to Fort Apache, across the Natanes Plateau. Thornber (1905) described the Natanes Plateau, which in many places has almost no herbaceous vegetation beneath the pines today, as follows: "The region is one for the most part ungrazed, the bunches of grass maturing large quantities of seed and then dying down to the ground again, thus forming a good surface covering. Also the more or less continuous forest covering contributes considerable in the way of protection for the grasses, so that effects of excessive drought and heat are modified. With the above conditions, it would hardly be too much, except in the densely shaded portions, to expect a continuous turf or sod, but such is the case only for small areas. Most if not all of the grasses are of the xerophytic bunchgrass type; these bunches usually occur at intervals of a few inches to a few feet. They are apparently as abundant on one slope as another. Between these bunches of grass are interspersed many annual and perennial species, so that there is quite a continuous vegetative covering everywhere over the mountains. In addition to the forest layer, already noted, and the layer of herbs and grasses, there is a fairly well-defined shrub and undershrub layer; in ordinarily closely browzed foot hills and mountains many of these shrubs are considerably browzed by cattle, but so far as could be seen none of these have been nibbled in the least. . . . The region also showed no sign of erosion or gullying, except perhaps where dug away by the hand of man, as along the road." Further on, as he travelled from Fort Apache toward the town of Pinetop, he noted, "There is a thin layer of perennial grasses, covering most of the land from Cooley's to Fort Apache, although it rarely approaches a turf. At this time there is good grazing, but few or no cattle."

At the time of Thornber's visit such good range conditions could probably have been found only on the Indian reservations. More typical were the conditions that Plummer (1904) found on the Black Mesa Forest Reserve. Here forage grasses grew luxuriantly, but only at a distance from water. Carcasses of cattle and horses showed where they had died of thirst after getting too far from water in search of pasture. Beaver Creek, a tributary of the Verde River, was cited as an example of overstocking, resulting in the "complete annihilation of pasture in a formerly rich area."

Deterioration of watershed condition began comparatively early. Bryan (1925) stated that the Rio de Flag, a small creek flowing through a grassy flood plain in the pine region near Flagstaff, had entrenched itself in an arroyo 10 to 20 ft deep. He dated this trenching from 1890 to 1892. That gullies originally were rare in the forest area can be inferred from Dutton's (1887) comments about the Kaibab Plateau: ". . . every ravine is as smooth as a lawn and carpeted with a rich turf of mountain grass, richly decked with flowers of rare beauty and luxuriance."

Pattie (1905) camped on the Gila River in 1826, apparently not far below Gila Hot Springs. He said, "I began to ascend the bank of the stream to explore. . . . The first day we were fatigued by the difficulty of getting through the high grass, which covered the heavily timbered bottom." There is little grass in the eroded Gila Canyon today. Leopold (1921) said of Blue River, a tributary of the upper Gila, "All the old settlers agree that the bottoms of Blue River were, at the time of settlement in about 1885, stirrup-high in gramma grass, and covered with groves of mixed hardwoods and pine. The banks were lined with willows and abundant with trout. . . . About 1900, fifteen years after settlement, floods began to cut an ever-widening channel."

Wheeler (1878) stated that in the White Mountains, "Elk, mountain sheep, California lion, deer, antelope, wild turkey are known to be abundant in this range, and their fresh tracks were constantly seen." But game was not always plentiful. Nelson (1884) wrote that ". . . the twentieth of August found us located at Springerville. . . . Although the mountains about here have been noted for the abundance of game in them during past years, yet all kinds of large game were remarkably scarce during the past season. . . . Bear were not to be found at all, and elk were so scarce that only a single fresh track was seen during several weeks in the woods. Although the cattlemen have invaded the district in force, yet they have only touched the pine country at widely scattered places, and I am unable to account for the scarcity of large game." At about the same time, Frazier (1884) visited the Apache Reservation on behalf of the Indian Rights Association. He reported that "Game is scarce on the reservation, and the Indians find it difficult to find animal food." Even earlier, Indian Commissioner Dole noted a shortage of game at the time of the Civil War (Ogle 1940). Thus it appears that big game was by turns abundant and locally scarce even before white men had much influence on the region.

The most notable game animal in Arizona was the Merriam elk, now extinct. Its principal range was the White Mountains, but it occurred throughout Arizona and New Mexico. It was reported around Flagstaff as late as 1884, and apparently persisted in isolated areas until the early years of the present century. Rocky Mountain elk have since been transplanted to Arizona.

The history of deer in Arizona has been one of alternating scarcity and overabundance. In most of the mountain areas of the state deer have thrived in recent years and are probably at least as numerous as they have ever been. No really radical changes have been noted in the abundance of most of the other conspicuous forest animals—wild turkeys, squirrels, and others. An intensive predator control program has eliminated the grizzly bear and the wolf, and considerably reduced the numbers of bear, coyotes, and mountain lion.

Changes in the Arizona pine forests were summarized more than 50 yrs ago by Holsinger (1902), an examiner for the General Land Office: "Briefly, the history of the forests of Arizona, which my opportunities have enabled me to gather from many of the oldest reliable pioneers, is that when first invaded by white man the forests were open, devoid of undergrowth, and consisted in the main of mature trees, with practically no forest cover. Instead of forest undergrowth, the ground was well set with perennial grasses and other herbage, which, being undisturbed, maintained what may be called a normal condition, or such as existed when the country was first settled and such as is now much to be desired. It was not an uncommon thing for the early settlers to cut native hay in the pine forests and fill large government contracts at the different military posts. As an instance, Fort Whipple, near what is now the Prescott forest reserve, may be mentioned. Where hundreds of tons of hay were cut under the actual spread of the forest trees during the sixties and seventies, there is not now enough grass on a thousand acres to keep in condition a family cow. Where were then running streams are now dry arroyos, and where were then living springs are now beds of silt and sand."

An examination of the record tends to substantiate Holsinger's conclusions. The forest was decidedly open and parklike. Reproduction was present but not abundant, and in many areas was markedly deficient. Grass was abundant, but not universal. Wildlife was probably little if any more plentiful than today, although some species such as the grizzly bear and the lobo wolf have long since disappeared from the state.

The most conspicuous change that has taken place in most parts of the region is the increase in area and density of pine reproduction stands (Fig. 1). Few parts of the southwestern pine region today lack young trees. Grass density has been greatly reduced, and in some places ground cover vegetation is virtually absent (Fig. 2). A combination of factors, operating over the past 75 yrs, has brought these changes about.

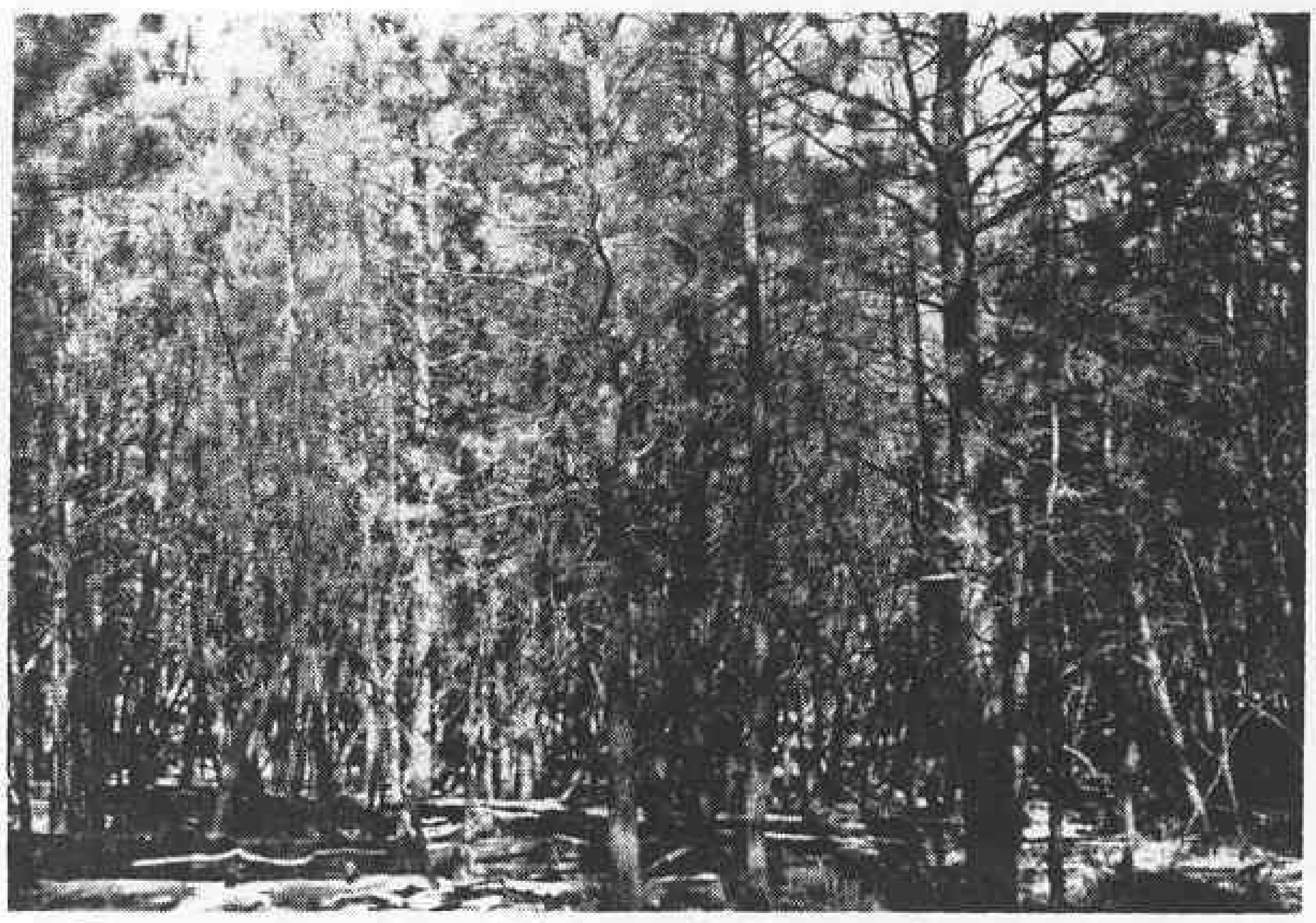

FIG. 1. A typical thicket of 38-yr-old ponderosa pine. In the densest portion of this stand, there are the equivalent of 10,000 stems per A or more.

## CLIMATIC CHANGE

To evaluate the importance of climatic change, it is necessary to consider how climate affects the growth and reproduction of ponderosa pine. Moisture is the critical factor regulating the distribution of this species, and a severe dry period in the spring of the year hinders regeneration. In the Southwest, a peculiar combination of weather conditions must occur before seedlings can become established.

According to Maguire (1956), whenever average monthly temperatures during April and May are considerably above normal, ponderosa pine will flower in abundance the following spring, with resulting large cone crops in the fall of the next succeeding year. In the Southwest, good cone crops occur about once every 3 or 4 yrs, with a real bumper crop at irregular intervals (Pearson 1950:111). Establishment of a reproduction stand requires coincidence of a good seed crop and favorable growing conditions during the year or two after germination. Seeds commonly germinate in July and August, during the summer rains. If the rains are closely spaced, incredible numbers of seedlings sometimes germinate.

FIG. 2. A dense cover of mountain muhly (*Muhlenbergia montana*) is characteristic of moderately grazed pastures such as the one on the right. Overgrazing has eliminated virtually all herbaceous vegetation on the left side of the fence.

For instance, in September, 1957, as many as 30 to 40 seedlings per square foot could be counted in parts of the White Mountains. In a normal dry spring, no seedlings of the previous summer's crop will live. Only in an unusually wet spring can stand establishment be expected.

A peculiar combination of weather conditions, then, is needed to establish reproduction: a warm spring in one year, resulting in a heavy seed crop 27 months later. The summer and autumn after seed fall must be wet, and the following spring must also be wetter than normal. Such a combination of events in a semi-arid region can be considered a climatic accident, rather than a part of the normal weather pattern.

The available weather data from Arizona are of limited use in assessing long-term climatic change because of the shortness of the record. There was a severe drought in the last decade of the nineteenth century, a wet period from about 1904 to 1930, and a renewed drought since that time. The drought of the 1890's had a marked effect on the grazing history of the region, and was apparently severe enough to kill pine trees near the lower forest border. Plummer (1904) reported that trees were killed by drought in the vicinity of Heber and near Blue. There is no evidence, however, of a recent major change in climate.

One of the most publicized sources of long-term climatic data is analysis of tree rings. Tree ring studies in the Southwest have been carefully analyzed by Schulman (1956). He showed that an irregular alternation of wet and dry periods has been characteristic of the entire period of the existing tree ring record. In the Gila River basin, analyses of more than 100 trees show that there were marked dry periods in the years 1800-1825, 1841-1847, 1861-1864, 1871-1904, and 1921-1953. Wetter than usual periods were characteristic of the years 1826-1840, 1848-1860, 1865-1870, and 1905-1920. His general index for the entire Colorado River basin, which extends the record further back in time, shows similar irregular fluctuations for about 900 yrs back from the present. On the basis of tree-ring chronologies, Schulman (1956:67) stated that the current drought in the Gila River basin is the most severe since the late 1200's. This drought is interpreted as having begun in 1921 in some parts of the basin, in 1934 in others.

Schulman pointed out, however, that his analysis is based on ring widths measured as a percentage departure from a moving mean. Small secular changes in climate may be completely hidden by this moving mean procedure. Short-term departures (droughts and wet periods) from the mean are easily detectable, but longer-term changes in overall climate would not be evident from tree ring data.

Hack (1942) studied the evidence for long-term changes in the environment of the Hopi Indians, whose home is some 80 mi north of the forest area. He concluded from the stratigraphy of stabilized and active dunes that the climate was much drier than at present during the period from about 5000 to 2000 B.C., and that the climate of the first millenium A.D. was apparently moister than it is today. Stratigraphy of alluvial sediments in arroyo banks pointed to a similar conclusion, with a minor wet period between 1300 and 1700 A.D. Antevs (1955) concluded from geologic and archeologic evidence that there was a warm peak about 3000 yrs ago, followed by a rather abrupt decline to the general temperature of the present. There were severe droughts about 500 B.C. and 330 A.D., and during the years 1276-1299 and 1573-1593. Other comparable periods in the past thousand years have been somewhat wetter than the present.

On the basis of the rather scanty evidence available, there seems to be no reason to believe that there has been a large-scale climatic change in the past 1000 yrs of a type that would profoundly modify the character of the pine forest. Certainly there have been minor fluctuations, from relatively wet to relatively dry. The recent drought began about 1930, whereas the current overabundance of reproduction dates from at least a decade earlier.

The question of climatic accidents is less easily disposed of. There is no way to determine from the historical record how frequently the peculiar combination of events necessary to initiate extensive pine reproduction could have occurred in the past. The great spatial and temporal variability of precipitation described by McDonald (1956) makes it appear that such a combination is entirely a chance occurrence. Perhaps the 1919 reproduction year of which Pearson made so much was a highly improbable situation that could be expected to recur only once in several centuries. If so, the present condition of the pine forest might be ascribed in large part to this single climatic accident. It seems likely, though, that similar accidents have occurred since time immemorial. Climatic change, either in the form of long term trends or of an unusual combination of weather conditions in one period of years, does not appear to offer a satisfactory explanation of changes in the pine forest.

### Grazing

The overuse and mismanagement which followed introduction of livestock into the West produced profound changes, some of them permanent, in the plant cover. Because these changes were conspicuous and well publicized, the stockman has been blamed for many of the ills of forest land management. In particular, overgrazing has often been assigned as the primary cause of the overabundance of young pines.

Utilization of the ranges of northern Arizona did not begin to any great extent until the late 1870's. Within a few years after the subjugation of the Indians the ranges began to fill up. The Navajo country, including the pine area on the Defiance Plateau, was heavily grazed for years before that time, however. Charles Bent (1851), in a letter written during the Mexican War estimated that the Navajos possessed 30,000 cattle, 500,000 sheep, and 10,000 horses, mules, and asses. These figures seem a little high, but that the Navajos owned extensive herds is attested to by Lt. Simpson (1850), who wrote from Canyon de Chelly: "Innumerable signs of stock, principally sheep, have been seen along the route, and the road we have been travelling looks as if it might be one of the great thoroughfares of the nation." Unlike the Navajos, the Apaches kept no stock, preferring to steal animals that their neighbors had raised.

Sheep preceded cattle into most of the Arizona mountains. Heavy settlement of northeastern Arizona began about 1876, and few good locations remained unoccupied by 1880. Sheep outnumbered cattle by 10 to 1 at this time (Haskett, 1936). As cattle began to replace sheep, the mountains were used primarily by stockmen who had their headquarters in the shortgrass plains at lower elevations.

Social and economic conditions at that time were such as to prohibit conservative and intelligent management of the range, even had the requisite knowledge been available. Cattle prices were too low to permit ranchers to do much more than turn their cattle loose and gather the increase at periodic intervals. Virtually all the range was vacant and uncontrolled public land. While each outfit had its own "accustomed range" which was generally recognized, that range had to be occupied or someone else would move his stock in. Thus it became a race to place cattle on the summer ranges as soon as a spear of grass appeared, for fear of losing out altogether.

Under such conditions abuse and deterioration of the range was inevitable.

By 1889 Farish (1889) could write of the San Francisco Mountains: "In this mountain range are found fine valleys, formerly covered with a growth of wild rye and pea vine, which has been replaced by other grasses." Replacement of the better forage plants had taken no more than a dozen years after the introduction of livestock. In 1892 a severe drought combined with range depletion to cause heavy stock losses, which became even worse in 1893. The Governor of Arizona stated in his annual report: "In nearly all districts, owing to overstocking, many weeds have taken the place of the best grasses. In other places where ten years ago the end of the wet season would find a rich growth of grass, now it is of inferior quality, or less quantity, or does not exist at all." (Hughes 1893).

Conditions were probably at their worst by the turn of the century. Serious concern began to be felt about the influence of overgrazing on water supply. The water problem in relation to forests and forest grazing was made the basis of recommendations for government action in almost every report of the Territorial governors from 1893 to 1910. In the summer of 1910, Sam F. Webb, a representative of the Salt River Valley Water Supply Protective Association, toured the mountains with Gifford Pinchot. His report (Webb 1900) gives a good idea of range conditions in the forest at that time. Speaking of Phoenix Park, between the Mogollon Rim and the town of Pinedale, he says, "Phoenix Park, which once claimed the distinction of being the best and finest portion of that part of the reserve, when we were there, had no running water. Its valley had been ruined by a deep cut or wash draining it so as to render it uninhabited." This is still true today.

At about the same time, Plummer (1904), writing of the present Apache National Forest, reported, "The entire reserve is a natural range, and grazing has been the main industry in this and adjacent regions. In recent years this industry has suffered greatly owing to the continued droughts, and the only remaining areas which are used solely for cattle range are on the Blue and Salt Rivers and Eagle Creek. The Double Circle Ranch, which used to graze over 100,000 head, has been compelled to gradually decrease its herd, until it now numbers not more than 9000. Range for this herd is very limited, and large areas are now being rented from the Apache Indians in the White Mountain Indian Reservation."

As this last statement implies, conditions were somewhat better on the Apache Reservation. Webb (1900) stated, "The White Mountain Indian Reserve was visited and the parks in it showed no deep cuts or channels to carry the rain water away in torrents." Webb attributed this difference entirely to differences in grazing use. He did not appreciate that the soil of Phoenix Park is highly erodible when disturbed, while the basalt soils of the Indian Reservation are much less susceptible to erosion (Fletcher & Beutner 1941).

There is apparently less grass in most of the mountains of Arizona today than there was at the coming of the white man. Two factors have tended to reduce forage production on pine bunchgrass ranges (Arnold 1950). Under heavy grazing the original tall bunchgrasses have been largely replaced by plants more resistant to grazing, except where dense tree cover discourages livestock use. In addition, grass cover decreases as pine reproduction becomes established; the greater the density of pine saplings, the less the total herbaceous cover. Decline in total forage production as a result of competition from young pine stands is accompanied by no great botanical change in the herbaceous vegetation, but heavy grazing induces a major change in species composition. In openings within the forest, ranges in good to excellent condition near Flagstaff support a high proportion of midgrasses, dominated by Arizona fescue, mountain muhly, muttongrass, and June grass. Under heavy grazing pressure, the midgrasses are replaced by a shortgrass cover composed largely of blue grama and squirreltail. Under still more severe use, even these resistant grasses are largely replaced by less desirable perennial and annual forbs (Arnold 1955).

The adverse effects of overgrazing on soil and water movement have been described so often that little repetition is needed here. Arnold (1955) reported that of the mountain meadows examined in northern Arizona, those in excellent condition showed no gullies. Two of the 13 meadows classed as good had gullies, but these were less than 2 ft deep. The degree of gullying increased to the point that of 14 meadows in very poor conditions, 10 had deep gullies and 2 had shallow gullies. Degree of gullying, however, is in considerable degree dependent on the erodibility of the soil. Fletcher & Beutner (1941) showed that basalt soils were far less erodible than soils supporting a similar vegetation but derived from sedimentary rocks or granite. This is apparent in the White Mountains, where severe gullies rarely develop in the basalt soils, even under heavy range abuse, although soils derived from other rock types are often badly eroded.

Browsing by livestock has had a direct effect on pine reproduction, particularly in the early days of heavy grazing. Pearson (1950:157) discussed in some detail the relation of regeneration to browsing animals. Sheep eat both growing shoots and needles, while cattle normally eat only shoots. This difference in feeding habits, plus the heavy grazing that results from the close herding of sheep, makes sheep more damaging than cattle. In the early years of this century, many areas were completely denuded by sheep. Webb (1900) reported that south of Springerville, "From 1875 to 1882 Tranquilino Luna is reported to have had sixty thousand sheep grazing annually on the Gila Forest reserve, and made Luna and one or two neighboring localities his lambing grounds. Since that date but little stock has roamed over the region. When we were there no grass or anything in the shape of feed except a few scattering weeds could be seen. The grass roots and seeds have been destroyed. No young pines of over fifteen years growth were observed." Lieberg *et al.* (1904) also reported wholesale destruction of small pines by sheep on the San Francisco Mountain Forest Reserve.

The large reduction in numbers of livestock permitted on national forests, plus the extensive conversion of sheep operations to cattle, have greatly alleviated the browsing problem. Localized damage continues due to livestock concentration, but is relatively minor. The results of past browsing damage, however, are clearly apparent in large areas that lack reproduction due to past sheep use.

Grazing has been important in reducing the spread of fire. Large amounts of inflammable grass, which used to remain on the ground, are now removed by grazing animals. Many of the early arguments against reduction of grazing on the national forests were based on the premise that heavy grazing made forest fires much less frequent.

It has been widely held that removal of herbaceous cover and plant litter by grazing animals, and the exposure of mineral seedbeds by livestock trampling have been important factors in the establishment of dense pine stands. Pine seeds germinate well under proper weather conditions on almost any type of ground cover, but they soon die from desiccation unless they become rooted in mineral soil. In addition, direct root competition for soil water from the established grass cover is considered to inhibit seedling growth. Rummel (1951) compared Meek's Table, an ungrazed mesa in central Washington, with Devil's Table, a grazed mesa supporting a dense stand of young ponderosa pine. He concluded that herbaceous vegetation as dense as that found on Meek's Table definitely inhibited establishment of ponderosa pine reproduction. His study did not indicate the critical density of ground cover vegetation which would permit the establishment of either adequate or overabundant reproduction. His discussion clearly implies, however, that there is an almost straight-line relationship between degree of reduction of the virgin herbaceous stratum and quantity of pine reproduction. He concluded that heavy grazing is the primary factor which accounts for the dense reproduction on Devil's Table.

In contrast, a much earlier study by Pearson (1923) in Arizona showed that "competition with grasses is less disastrous to yellow pine seedlings than might be expected." Although grass competition slowed seedling growth, stand regeneration proceeded even in the presence of a grass cover. Seedlings were severly handicappd in the densest grass areas, but even here a few were able to establish themselves.

Nearly 20 yrs later, Pearson (1942 confirmed earlier findings that dense herbaceous vegetation retards pine reproduction. Grass and other herbaceous plants are able to appropriate most of the moisture in the upper nine inches of soil at the expense of pine seedlings. Until they have developed a deep root system, grass competition puts the young pines at a disadvantage.

Lavin & Springfield (1955) planted ponderosa pine seed in a 2-yr-old artificially planted stand of herbaceous vegetation, of several species and densities. At the end of the second season, seedling survival was inversely related to the total coverage of the herbaceous plants, but the decrease in survival was only moderate as competition increased. They concluded that, "Although herbaceous vegetation, seeded and native alike, adversely affects pine seedling survival, fairly good survival was obtained in spite of this competition." Of course, the density of the reseeded grasses did not approach that of the natural vegetation that Rummel found on Meek's Table.

These studies show that ground cover vegetation strongly affects growth and survival of pine seedlings. Most of the studies cited do not devote enough attention to the unusual weather conditions required for pine reproduction. In a normal year, most if not all pine seedlings in a virgin forest will die regardless of competition. In the rare year in which a wave of seedlings establishes itself, there may be so much moisture that no degree of herbaceous competition is really inhibitory. Reduction of competition may be a means of encouraging better reproduction in managed stands, but under virgin conditions it appears that seedlings could have developed even in a heavy grass cover. The reduction of grass competition and the preparation of a mineral seedbed by grazing animals probably helped to bring about the dense thickets, but do not seem to have been the controlling factor. There are many severely grazed openings which remain nearly denuded of vegetation and in which pine seedlings have not become established.

### WILDLIFE

The relation of deer to the ponderosa pine forest has long been a matter of concern. The Kaibab deer herd has profoundly modified the vegetation of its range (Rasmussen 1941). As a result of removal of natural predators and of restriction of hunting, this herd built up from an estimated 4000 deer in 1906 to nearly 100,000 in 1924. By that time the range was depleted, there were deaths by the thousand from malnutrition, and the population dropped precipitously. Parts of the pine area were so severely browsed that reproduction was eliminated.

Elsewhere the deer problem has not been so acute. Pearson (1950) stated that deer eat pine buds early in spring when elongation begins, and occasionally they will take shoots that are distinctly woody. Deer tend to concentrate where use by livestock is light. On the whole, deer have probably played a relatively small part in recent changes in the pine forest. Heavy hunting pressure greatly reduced deer populations in most of Arizona, except the Kaibab Plateau, during the early years of this century, and only recently has the deer herd built up to its present level. Elk, never very common, were quickly exterminated, and the introduced elk are not numerous enough to have more than a local effect on vegetation. Obvious browsing by elk was noted in the upper branches of small pines after they were cut on experimental plots near Maverick in November, 1957.

Rodents and other small mammals were considered very important by Pearson (1950:151). He was concerned about the use of seeds by mammals, the girdling or complete cutting of seedlings, and the removal of bark from larger trees. Taylor & Gorsuch (1932) found that birds, ground squirrels, chipmunks, and mice all ate pine seeds. They concluded, though, that under natural conditions seed-eating rodents have little or no detrimental effect on reproduction of ponderosa pine. When favorable conditions occur, seedlings develop in spite of all obstacles.

Keith (1956) made a thorough study of the Abert squirrel, which Pearson classed as one of the most damaging of animal agents. Keith concluded that the squirrel is well adjusted to the climax forest, and that it has very little real effect on the forest as a whole. There is little basis for assuming that wild animals have been more than a minor factor in inducing changes in the pine forest in historic times.

## FIRE

The principal assignment of the early foresters in the Southwest was the exclusion of fire from the woods. They recognized that fires had been frequent, and that a surface fire could pass through a ponderosa pine forest without destroying it, but each such fire was considered another step contributing to final destruction. John Wesley Powell (1879) believed that "The protection of the forests of the entire Arid Region of the United States is reduced to one single problem—Can the forests be saved from fire?"

Reporting on the newly formed San Francisco Mountain Forest Reserve, Lieberg *et al.* (1904) wrote: "It is very evident that the yellow pine stands, even when entirely untouched by the ax, do not carry an average crop of more than 40 per cent. of the timber they are capable of producing. . . . These conditions are chiefly attributable to the numerous fires which have swept over the region within the last two hundred years, carrying with them the inevitable consequences of suppression and destruction of seedling and sapling growth."

There is little doubt that fires, started by lightning or by Indians, were frequent in the pine forest before the arrival of the white man and in the early years of settlement. Weaver (1951a) analyzed the fire scars on stump sections collected at various sites in Arizona. The most frequently burned tree showed an average interval of 4.8 yrs between fires, while the longest average interval between fires exhibited by any sample tree was 11.9 yrs. Weaver's data are borne out by the results Show & Kotok (1924) obtained in California. They found that during the 200 yrs for which the tree ring record is fairly complete, 25 clearly marked fires were detectable. The average fire frequency of about 8 yrs held true for all California areas studied. The shortest interval between fires was 3 yrs and the longest 11 yrs.

Early visitors to the Southwest apparently took for granted the frequency of surface fires in the pine forest. Wheeler (1878) was a few miles north of Black River on August 27, 1873, when he wrote, "Here, as has been noticed in several other localities, the grass on one side of a stream will be new, juicy, and thin, because of the burning of the sward during the season, while on the opposite side, where no burning has taken place, the thick tufts of bunch grass spreading into beds offer more abundant feed for the animals that now have to depend upon grass altogether for their support."

Despite the frequency of surface fires, serious crown fires were apparently rare. A fairly thorough search of the early literature failed to turn up a single report of a crown fire in Arizona before 1900. A Forest Service report (Drake 1910) on the Coconino National Forest stated that over 80% of the yellow pine type had been burned over one or more times, but that the fires usually destroyed only a small amount of standing timber. Only two burns were noted which destroyed the stand: one of 7000 A in spruce about 30 yrs previously, and the other of 3200 A in juniper woodland near Winona. With the possible exception of a part of the Prescott National Forest, there appears to be no area in Arizona where extensive even-aged pole stands indicate that a major fire destroyed most of the mature timber and permitted extensive even-aged regeneration. There is no evidence elsewhere of fires of the magnitude of the Escudilla fire of July, 1951, which destroyed most of the timber on 19,000 A, or the 21,000 A Dudley Lake fire of June, 1956.

The situation in California ponderosa pine was evidently similar to that in the Southwest. Sudworth (1897), reporting on the Stanislaus and Lake Tahoe Forest Reserve, said, "The fires of today are peculiarly of a surface nature, and there is no reason to believe that any other type of fire has occurred here. . . . The instances where large timber has been killed outright by surface fires are comparatively rare. Two cases only were found. . . . One of these burns involved less than an acre, and the other included several hundred acres. They are exceptional cases, and the killing of the trees is accounted for by the fact that protection from fire and from all but cattle grazing has resulted in the accumulation of much fallen timber, considerable humus in depressions and on benches, and a dense undergrowth of brush and seedlings."

The occurrence of forest fires far back into antiquity was noted by Holsinger (1902). In Chaco Canyon, New Mexico, he found that where a deep arroyo had cut to a depth of 30 ft through a sedimentary formation, distinct strata of earth, impregnated with charcoal, lay about 15 to 20 ft from the surface and could be traced over an area of several thousand acres.

Opinions of early foresters about fire in ponderosa pine were summarized in the detailed study of Show

& Kotok (1924) on the role of fire in the pine forests of California. They concluded that "The present California pine forests represent patchy, understocked stands worn down by the attrition of repeated light fires. . . . Each successive fire adds its often imperceptible weight to the force of attrition that thins the stand, weeds out the finest individual trees, and gradually reduces the forest in quantity and quality to the point where the returns will not justify the cost of logging." They reported that each fire burned down a portion of the mature stand by enlargement of old fire scars, reduced growth rates by physically injuring the trees, and rendered them more susceptible to attack by insects and disease. Young growth suffered most severely from fire. The most conspicuous result of 20 yrs of fire protection in California was "the enormous number of young forest trees that have appeared as individuals or as groups, or in the more virgin stand as a veritable blanket under the mature timber." They concluded that a small amount of reproduction, patchily distributed, is able to survive ground fires, but most of the young stand is inevitably wiped out. In consequence, they felt that fire exclusion would permit nature "to utilize the full growing power of the land, and to restore the broken and understocked forest to a more normal condition."

Dissenting views were heard even in those days. The Annual Report of the Secretary of Agriculture for 1910 said that "The proposal has been made that the Forests should be burned over every year or two in order to prevent the accumulation of vegetable litter on the ground. It has been alleged that the fires which were set in the early days by the Indians and the first settlers were beneficial. As a matter of fact, these early fires were enormously destructive." (U.S. Dept. Agr. 1910). This proposal was dismissed out of hand with the statement, "It is inconceivable that there should be seriously advocated a treatment of the forest that would inevitably result in the very rapid dimunition of its density to the point where ultimately there would be no timber at all."

### The Indian, Fire, and the Forest

There is abundant evidence that Indians were responsible for many fires. Stevenson (1881) stated that Indians set fire to the timber on the mountain ranges of New Mexico each fall in order to drive deer down into the canyons. John Wesley Powell (1879) stated that Indians systematically set fire to the forest for the purpose of driving game. The early pioneers of Kanab, Utah, saw great clouds of smoke rolling over the Kaibab Plateau almost continuously from late spring to early fall. Indians were still killing white men in those days, so few trips were made to observe the fires. It was said that Indians chased deer and other game out on the points overlooking the Grand Canyon and then set fires behind them to concentrate game on the very tips (McHenry 1935). On his return from the first ascent of Mt. Baldy, Wheeler (1878) reported that on the higher reaches of the Little Colorado, "For a little less than 2 miles the grass is of the old crop, then begins the new and juicy growth of the year subsequent to the burning over by fires set by Indians."

Indians had many reasons for setting fires. "The most potent and powerful weapon in the hands of these aborigines was the firebrand. It was used alike to capture the deer, the elk, and the antelope, and to vanquish the enemy. It cleared the mountain trail and destroyed the cover in which their quarry took refuge." (Holsinger 1902). According to Bell (1870), "The Apaches also have a very destructive habit amongst their long catalogue of vices of firing the forests of their enemies." On his trip through the Indian reservation, Webb (1900) found fires burning in two places, which he said were "attributable to the Indians who believe fire and smoke bring rain."

Holsinger (1902) was convinced that "These prehistoric aborigines must have exerted a marked influence upon the vegetation of the country. Their fires, and those of the historic races, unquestionably account for the open condition of the forest, to which reference has been made. The high pine forests were their hunting grounds, and the vast areas of foothills and plateaus, covered with nut-bearing pines, their harvest fields. . . . In Arizona you will find no young forests of any considerable extent antedating a period of forty years, and almost all of the regrowth has sprung up within the last quarter of a century. A single exception can be noted in the White Mountains, which have been occupied for a couple of centuries by the Apache Indians. These forests show, in certain localities, all classes of regrowth, and are in marked contrast to the mountain country occupied by the Navajo Indians in the northeastern portion of the Territory. The Navajoes have possessed sheep and goats and followed pastoral pursuits for over two centuries. The forest occupied by them shows practically no regrowth. The Apaches have followed the chase and war, and have entrammeled themselves with nothing but war ponies. The forests within their domain, where they have not seen fit to apply the torch in accord with their well-grounded superstition that forest fires cause rain, show a regrowth gradating into many past decades."

## THE EVIDENCE FROM STAND STRUCTURE

### Area of Study

Field work was completed in the summer and fall of 1957, principally on the Fort Apache and San Carlos Indian Reservations. These two reservations lie in east central Arizona, the Fort Apache to the north and the San Carlos to the south of Black River. The ponderosa pine forests of the reservations total about 700,000 acres, mostly on the Fort Apache.

The study area lies in the White Mountains, which form the eastern end of the Mogollon Plateau. East of about longitude 110° and south of the steep escarpment of the Mogollon Rim, the plateau is thickly mantled by Tertiary igneous rocks extruded from the extinct volcanoes that form the heart of the White Mountains. Lava flows, probably of Quaternary age, are superimposed on the older topography in the valley of White River and elsewhere (Darton 1925).

The topography of this great lava flow is relatively gentle for a mountain region. Although it is dissected by many steep-walled canyons, its general aspect is that of a gently rolling plateau. The two major peaks of the White Mountains, Mount Ord and Mount Baldy, reach elevations of 10,800 ft and 11,500 ft respectively, but most of the plateau lies below 9500 ft.

The basalt lava which overlies most of the White Mountains is relatively uniform in its composition, as are the resultant soils. One reason for choosing the White Mountains as a study area is the uniformity of its geologic origin, which largely eliminates the influence of differences in parent material on soil development and on plant growth.

Intensive field sampling was concentrated in three areas. The first of these was the old-growth forest about 10 mi west of Maverick, on the east side of Odart Mountain. Studies of reproduction stands were made along Bog Creek, east of McNary, in an area selectively logged in the 1930's. These two locations are about 40 mi apart airline, at an elevation of about 8,000 ft. Soils, climate, and topography are closely similar at both locations, and both are in the heart of some of the best pine forest in Arizona.

The third sampling area was the relatively untouched primitive area around Malay Gap, in the extreme northeast corner of the San Carlos Indian Reservation. This is perhaps the closest approach to a truly primeval forest left in the Southwest. Until the last few years there has been no usable stock water in the vicinity, so it has been grazed lightly if at all by domestic stock. Its remoteness and lack of roads have kept out all but a few visitors, and until very recently there was no adequate program for the control of natural fires. Malay Gap lies at an elevation of about 7,200 ft, and represents a somewhat less productive site for the growth of pine timber than the other two locations.

The controlled burning program on the Fort Apache Reservation gave an opportunity for several special studies. Since 1950, more than 150,000 A of pine forest have been treated with controlled fire, primarily to reduce fire hazard. Secondary objectives are partial thinning and pruning of sapling stands, and improvement of forage growth.

These have been extensive, large-scale burns. Firing is done in late fall, after the first of the fall rains but before the surface litter is too wet to burn. Buttes and ridges are ignited at the top to permit the fire to burn slowly and evenly downhill. Roads, rivers, and openings are used as backstops to restrict the area of the burn, but no effort is made to limit the fire to small blocks of a few acres.

While the Indian Service foresters feel that in general these controlled burns have achieved their objectives, strong dissenting opinions have been voiced by others who have viewed the results. The objective of this paper is not to evaluate the management accomplishments or the effectiveness of the present controlled burning program. It was possible, though, to take advantage of some of the treated areas to study the effects of fire on vegetation and soils. Although the planned fires burn later in the year than the majority of natural fires, the results of the controlled burns can aid in the interpretation of the role of natural fires in the forest.

## AGE AND SIZE CLASS DISTRIBUTIONS IN OLD-GROWTH STANDS

### DIAMETER CLASS DISTRIBUTIONS

In an uneven-aged forest with a balanced distribution of diameter classes, the proportion of trees in each class remains relatively constant with time. The diameter distribution usually takes the form of a falling exponential curve when number of trees in each class is plotted against d.b.h. On semi-logarithmic paper this relationship is a straight line.

The relationship between diameter classes may be visualized by dividing the number of trees in any one diameter class by the number in the next larger size class. In a stable, balanced forest, the resulting quotient is a constant. This constant may vary widely from stand to stand, depending upon species and environmental conditions. This definition of a balanced forest is called de Liocourt's Law, from the French forester who first formulated it (Meyer & Stevenson 1943).

The structure of the Southwestern ponderosa pine forest is actually that of an all-aged forest composed of even-aged groups, but in blocks of several thousand acres it can be regarded as an uneven-aged forest. Tree diameters derived, for instance, from a large scale timber inventory should be distributed according to de Liocourt's Law if the forest as a whole is properly balanced.

A detailed timber inventory of the Maverick Working Circle, Fort Apache Indian Reservation, was made available by Southwest Lumber Mills, Inc. This report included stand tables giving the average number of trees per acre by 2-inch diameter class for all stands distinctive in character or geographical location and of significant extent. These tables were based on data secured in 1951 and 1952 by Hammon, Jensen & Wallen Mapping and Forestry Services of Oakland, California. Modern photogrammetric techniques were combined with field data from random ⅕ A sample plots to prepare this inventory. A similar timber inventory, made for the San Carlos Apache Tribe by K. B. Woods, Inc., of Portland, Oregon, was available for the Malay Gap area.

Stand tables computed from 165 survey plots in the Maverick area and 90 at Malay Gap show that these old-growth forests do not have the diameter structure expected in a balanced forest. On the best sites in the Maverick Unit, numbers of trees per acre in the diameter classes above 20 in. follow the expected linear relationship when plotted on semi-log paper (Fig. 3). The number of trees in the 4-in. class, the smallest recognized in the timber inventory, falls on the projected line of the larger trees.

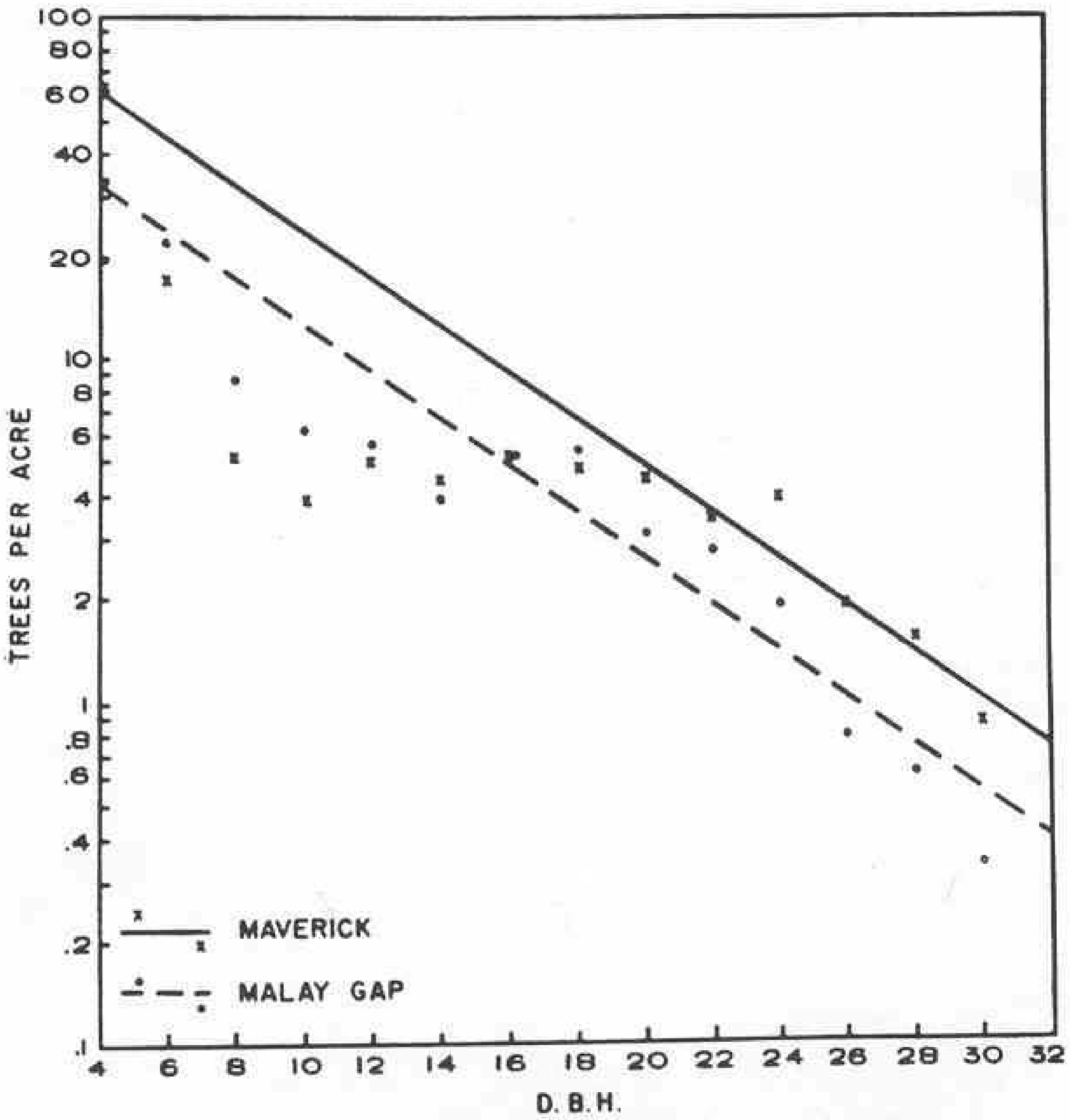


FIG. 3. Trees per acre as a function of diameter class at Maverick and at Malay Gap. Plotted points are the estimated number of trees in each diameter class as reported by timber inventory. Theoretical distributions are plotted from the larger size classes, according to de Liocourt's Law.

In all size classes between 4 and 20 in. d.b.h., there are fewer trees than are expected on the basis of the theoretical de Liocourt ratio. The same is true at Malay Gap. Numbers of trees in the size classes above 20 in., and in the 4- and 6-in. classes, plot on a straight line. Intermediate classes are somewhat deficient, although less so than in the Maverick Unit. The two lines plotted in Figure 3 are parallel, indicating that the same proportionate relationship between diameter classes is common to both areas. The difference in the position of the lines reflects the lower stand density at Malay Gap.

## AGE CLASS DISTRIBUTIONS

Age data were obtained primarily from increment cores taken from most of the trees on a square plot of 10.24 A at Maverick, and on one of 5.12 A at Malay Gap. Mature trees were also sampled on a number of random plots established for other purposes. The sample trees were bored to the pith about 1 ft above the ground, and the cores were aged according to the methods developed by Dr. A. E. Douglass and his associates at the University of Arizona Laboratory of Tree Ring Research. The dating procedure is based on visual comparison of wide and narrow rings. Ring sequences tend to occur in a regular pattern, which can be used to locate certain key dates. This system has marked advantages over direct counting of rings. Both missing rings and double rings are common in ponderosa pine, and are apt to confuse the results of a direct ring count. Errors are inevitable even with a cross-dating technique, but the ages reported here are probably correct to within five years. To the age as determined from the core must be added the length of time required for a seedling to grow to a height of 1 ft.

Ages are much more difficult to determine in a forest stand than are diameters. The sheer volume of work involved in boring trees and analyzing cores makes an extensive age sampling survey impractical. Ring counts on stumps, although often reported, are likewise unsatisfactory. Stump counts are ordinarily possible only on selective logging operations, where just the largest and least vigorous trees are cut. Even if all the trees are cut and their rings exposed, field counting of ponderosa pine rings is highly unreliable. Ages are best determined by use of accepted cross-dating techniques on properly surfaced cores.

An age class distribution could have been derived by calculating a regression equation relating the ages of bored trees to their diameters, and then applying the resulting regression coefficient to the stand table data from the timber inventory. There is so much variation in diameter within a single age class, however, that such an analysis would be almost meaningless. Pearson (1950:39) reported that trees in the 130-yr age class near Flagstaff ranged in diameter from 9.7 in. to 40.5 in., while those in the 246-yr class varied from 14.8 to 46.8 in. d.b.h.

Partial stratification can reduce the variability of age data. The Maverick timber inventory divided the trees in each diameter class into a number of subdivisions according to Keen tree class, a classification based on age and vigor of the individual tree. Four age classes are recognized, from immature trees to overmature veterans. Within each age class, four vigor classes are identified, depending upon size and thriftiness of the crowns. Thus there are a total of 16 possible classes. Trees of the same d.b.h. in a single Keen class are apt to be more similar in age than are those in an unstratified sample of the same size. Therefore, each sample tree bored for total age was classified according to the Keen system. For each of the 16 classes, diameter was plotted over age and a free-hand curve fitted to the points. The data were too few and too scattered to permit a satisfactory least-squares equation to be developed, particularly as the relationships were distinctly curvilinear. On the basis of the similarity of plotted points, the separate curves for some of the Keen tree classes were combined.

The final age-diameter curves were based on 107 trees from the Maverick area. From these curves and from the inventory stand tables, new stand tables were constructed for four of the distinct forest types distinguished by the timber inventory. These tables show the estimated number of trees and the basal area per acre contributed by each 20-yr age class (Fig. 4). Since the timber inventory included no trees less than 4 in. d.b.h., and since it takes at least 20 yrs for the average tree to reach 4 in., the 21- to 40-yr age class is the youngest included in the computations.

In each of the four age distributions shown in Figure 4, there is a relative lack of trees in the 100- to 120-yr age class, and an apparent overabundance

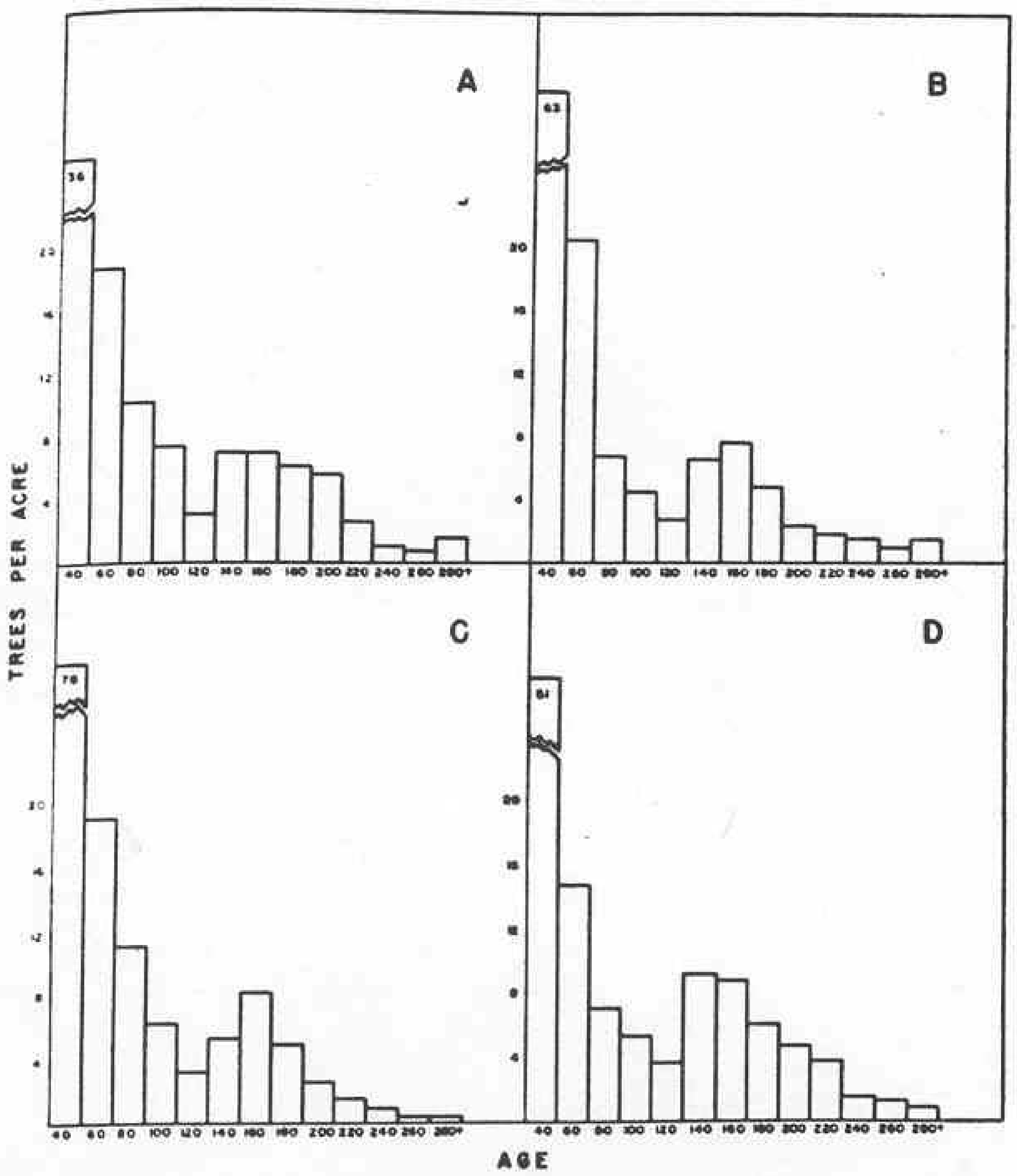


FIG. 4. Calculated number of trees per acre in each 20-yr age class in four selected stands at Maverick. Number beneath each bar is last year in age class.

in some of the older groups. An unbalanced age distribution is likewise evident on a single 10.24 A plot at Maverick (Fig. 5). This single plot was judged to be representative of the area as a whole, but it is by no means a random sample.

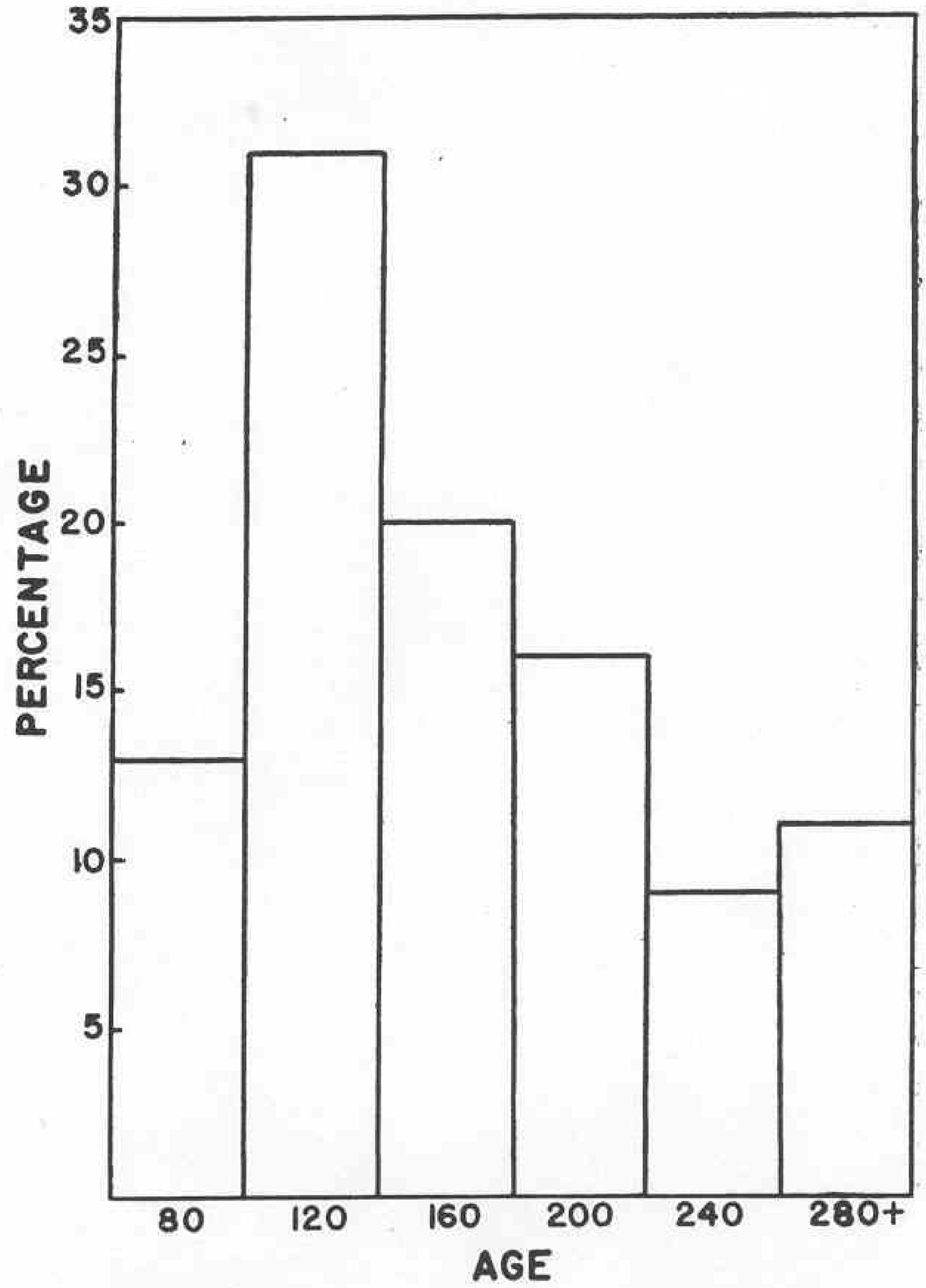


FIG. 5. Age distribution, by 40-yr age classes, of trees on intensively sampled 10-A plot at Maverick.

Just as important as the numerical distribution by age class is the proportion of the total ground space occupied by trees of each age class. At each of a series of random points at Malay Gap, the nearest tree in the dominant stand was bored for total age. The percentage of the total area dominated by trees of each age class was calculated from 42 sample points (Fig. 6). Sapling stands 21 to 40 yrs of age, and stands aged 100 to 180 yrs control most of the ground at Malay Gap.

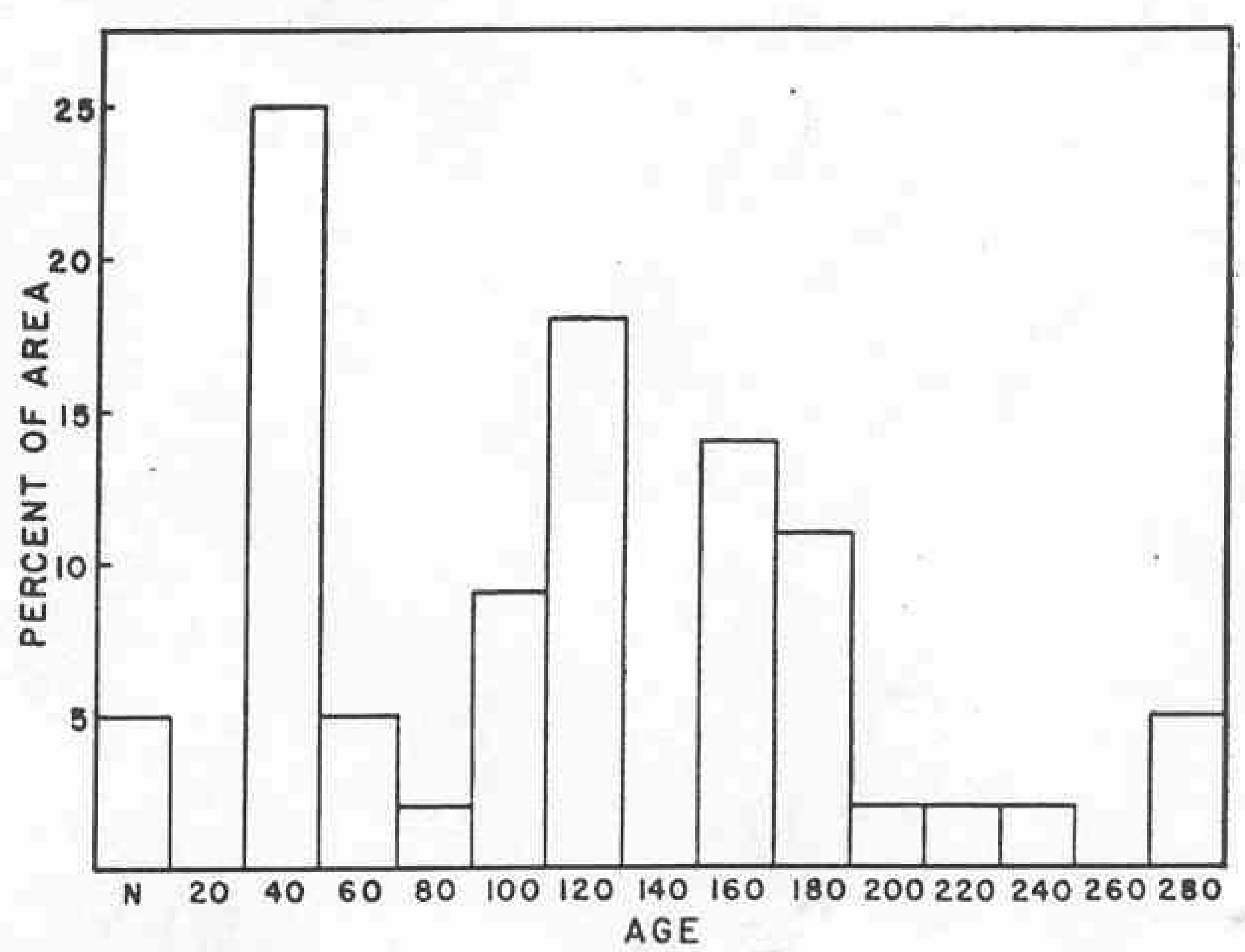


FIG. 6. Percentage of total ground area occupied by trees in each 20-yr age class at Malay Gap. N means non-stocked.

It is the older trees which contribute the greatest basal area per acre at Maverick (Table 1). Basal area distribution by age class was calculated for four selected timber types of several thousand acres each. Trees aged from 140 to 200 yrs account for a high proportion of the total basal area in each, while the contribution of the intermediate age classes is low. The basal area of the youngest age classes is actually somewhat higher than that shown in Table 1, since the calculations on which the table is based included no trees less than 4 in. d.b.h.

In a balanced forest, the numbers of trees per acre in each age class should presumably follow somewhat the same exponential relationship as that postulated by de Liocourt's Law for diameter classes. Stand tables show a deficiency in number of trees in the intermediate age classes. The number of trees per acre in the youngest and in the older age classes are approximately those predicted by de Liocourt's Law, but the intervening classes fall far short.

If a forest is to maintain a stable age distribution over a long period, each of the important age classes must occupy approximately equal proportions of the available ground space. As a group of 120-yr-old trees grows into the 140-yr class, an equivalent area of 100-yr-old trees might be expected to grow into

TABLE 1. Basal area per acre by age class in selected stands, Maverick Unit.

| Age Class | Basal Area Per Acre | | | |
|---|---|---|---|---|
| | Stand 1 | Stand 2 | Stand 3 | Stand 4 |
| (years) | (sq. ft.) | (sq. ft.) | (sq. ft.) | (sq. ft.) |
| 21-40 | 5.46 | 3.15 | 4.48 | 6.83 |
| 41-60 | 3.59 | 3.18 | 2.51 | 3.42 |
| 61-80 | 3.41 | 4.81 | 3.63 | 7.38 |
| 81-100 | 3.24 | 5.08 | 3.20 | 4.36 |
| 101-120 | 2.60 | 3.20 | 3.40 | 3.04 |
| 121-140 | 9.86 | 9.64 | 13.02 | 7.87 |
| 141-160 | 16.82 | 12.85 | 17.33 | 17.00 |
| 161-180 | 13.38 | 10.95 | 15.92 | 13.65 |
| 181-200 | 7.53 | 12.70 | 11.06 | 7.62 |
| 201-220 | 6.43 | 8.91 | 9.99 | 5.15 |
| 221-240 | 5.84 | 3.79 | 5.47 | 3.48 |
| 241-260 | 4.14 | 2.19 | 4.66 | 1.10 |
| 261+ | 8.45 | 9.34 | 5.50 | 1.91 |

the 120 yr class. The lack of area balance is evident in the stands sampled at Malay Gap.

Somewhat similar considerations apply to basal area of trees per acre. Lexen (Pearson 1950:28) derived the theoretical stocking density and space requirement for well-stocked stands of ponderosa pine. His table shows that fully stocked stands, regardless of the diameter of trees comprising them, have an average basal area of about 100 sq ft per A. Basal area in fully stocked stands remains relatively constant as the trees grow older, with mortality compensating for growth. It is therefore logical to assume that in a balanced forest, each age class will account for an equal percentage of the total basal area. It is evident from Table 1 that this is not the case at Maverick.

## Structure and Growth of Sapling Stands

Young ponderosa pine stands of several ages were sampled at Maverick, at Bog Creek, and at Malay Gap. Circular plots were measured in fully developed, more or less uniform patches of reproduction, with the plot centers so placed that the entire plot fell within a sapling stand of about the same density throughout. In no sense was this sampling technique designed to estimate the average number of trees per acre on the area as a whole. Rather, it was aimed at gathering information about the structure and composition of the reproduction clumps themselves. The samples are believed to be representative of a majority of the pine thickets in the study area.

Plot size, either 1/10, 1/40, or 1/100 A, was selected so that there were about 30 to 50 trees on each. Diameter at breast height of each tree was measured to the nearest 1/10 in. On most of the plots, all trees under about 5 in. d.b.h. and many larger trees were felled, and a circular cross-section cut as near to the ground as possible. Increment borings, at about 9 in. above the ground, were taken from those trees that remained uncut. On a few plots, only a random sample of about one-fourth of all the trees was cut or bored. Only d.b.h. measurements and one or two age borings were made on many of the Malay Gap plots. Heights of cut trees were measured directly, and standing trees were measured with an Abney level.

Growth data and past tree diameters were obtained from the increment cores and stump sections collected on the sample plots. The circular cross-sections were sanded to a high polish for ring analysis, while the increment cores were glued to grooved blocks for permanence and ease of handling. Diameters inside bark near ground level were measured on all sample trees as they were at the end of the 1957 growing season, and as they had been in 1947, 1937, 1927, and earlier decades. Details of the measurement procedure have been reported elsewhere (Cooper, in press).

The diameter measurements were used to compute the stem area of each stand at the time of sampling and at several earlier decades. It should be noted that this stem area was calculated from measurements of diameter inside bark near ground level, and it will be this that is meant whenever the words "stem area" are used in this paper. Where basal area is referred to, it will mean basal area calculated in the conventional manner from measurements of d.b.h. outside bark. A regression equation calculated from those stands for which complete data were available indicates that

$$B.A. = 1.20\ S.A. - 19.9 \qquad (1)$$

where B.A. is basal area in square feet per acre and S.A. is stem area measured in the same units. The standard deviation of the regression coefficient is 0.03. This equation is applicable to a range of basal area from about 100 to 300 sq ft per A. A less precise but more easily interpreted relationship states that basal area in these stands is 1.09 times stem area.

Obviously, stand data for previous years include only those trees present in the stand at time of final sampling, and conclusions about growth or stand structure specifically exclude any trees that died in the years between stand initiation and 1957. Total stand growth per acre in ten years is, of course, the difference between stem area at any two successive decades, while mean growth per tree is determined by dividing total periodic stand growth by the number of trees contributing to that growth.

### Diameter Class Distributions in Even-Aged Reproduction Stands

Discrete even-aged groups, seldom more than one-half acre in size, are characteristic of the southwestern pine forest. In the dry climate of the Southwest, it is only in occasional years that seedlings can become established, so that virtually every tree in a single clump of sapling or pole size will have germinated in the same year. Once such an even-aged group develops, it is rarely possible for seedlings of succeeding year classes to become established within it. Diameter distributions in these even-aged pole stands may indicate some of the conditions under which the stands have developed.

Diameter distributions in even-aged forests have been studied by Meyer (1930), who fitted several mathematical series to diameter data. Jones (1945) suggested that the frequency distribution curve of diameter classes is of the binomial type, usually skew. More recently, Prodan (1953) has used the Charlier A-Function to describe diameter distributions. He constructed percentage frequency distributions of tree diameter, based on 2-cm diameter classes. The maximum percentage frequency, termed $h_{max}$, is used to characterize the resulting frequency curve. An $h_{max}$ of 14 means that 14% of all the trees in the stand are included in the 2-cm class containing the most trees. Prodan presented a series of tables giving the expected diameter distribution for each integral value of $h_{max}$.

Diameter distributions of several ponderosa pine stands have been fitted to Prodan's theoretical values. Data from 197 trees in an 80-yr-old stand at Cooley Mountain fit the expected distribution quite closely (Fig. 7). The diameters of a group of 39-yr-old trees at Malay Gap likewise correspond closely to those predicted by Prodan's tables. The Cooley Mountain stand became established and made most of its early growth before white men came to the Southwest; the Malay Gap stands are in an area still little influenced by man.

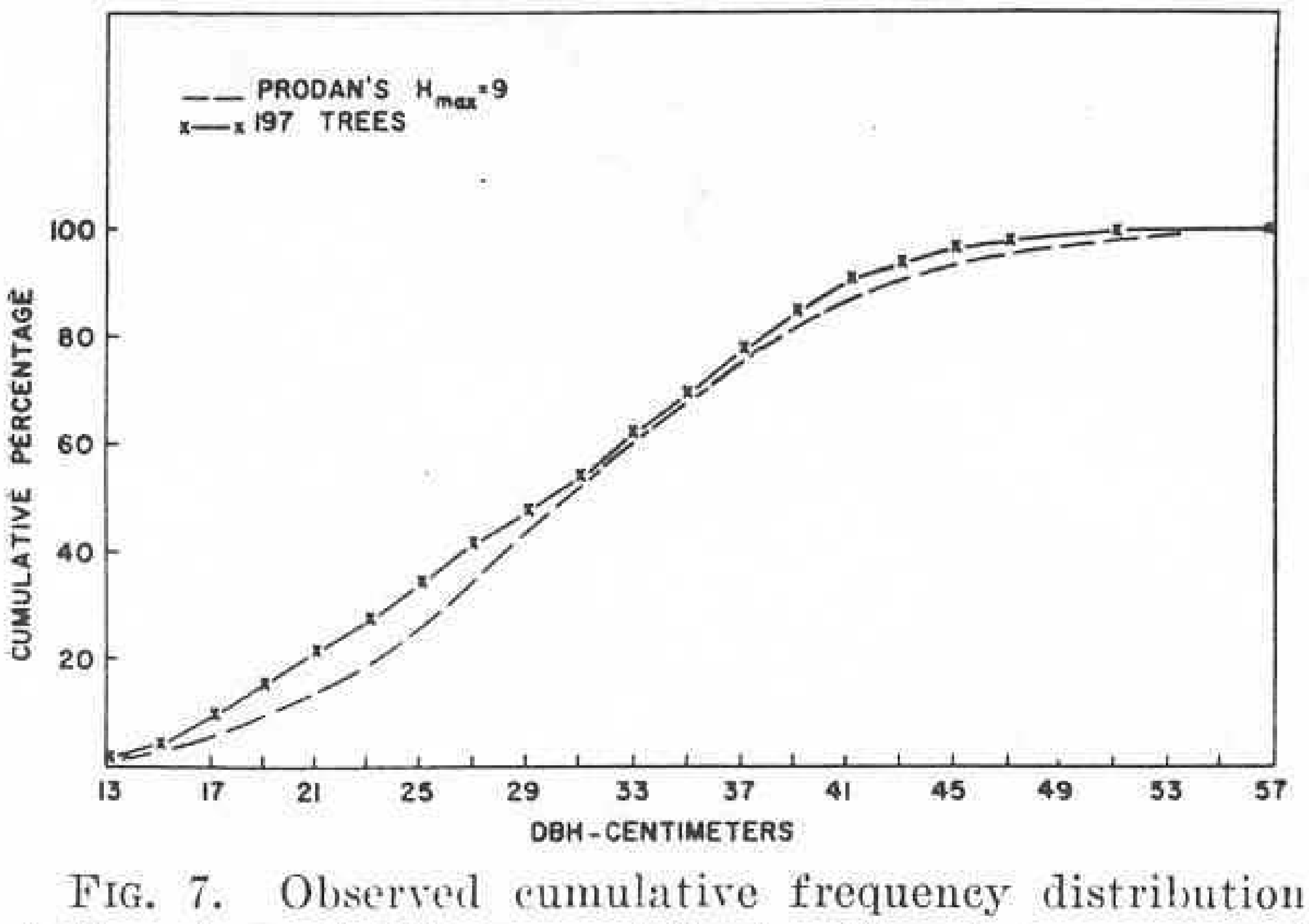


FIG. 7. Observed cumulative frequency distribution of diameters of 197 trees at Cooley Mountain, compared with distribution predicted from Prodan's theoretical relationship.

Diameter distributions of 33 stands sampled at Maverick and at Bog Creek deviate markedly from those predicted by Prodan's tables. In every case there are more small trees and fewer large ones than expected. The deviation is least in the 15 stands dating from the years 1903 to 1914, all of which were exposed to at least one and perhaps two fires at a very early age. The 18 younger stands, never touched by fire, show a greater preponderance of small trees.

A different approach has been used by Koyama & Kira (1956) in the study of the frequency distribution of individual plant weights. They concluded from experimental evidence that weights of seeds and very young seedlings usually follow a normal distribution. They showed by a mathematical model that the exponential nature of growth processes can result in a log-normal distribution of plant weights. A test of this log-normal hypothesis shows that frequency distributions of basal area in several ponderosa pine stands rather closely approach a log-normal form.

Six classes were used for each stand. Class interval was determined by dividing the difference between the logarithm of basal area of the largest tree on the plot and that of the smallest by 6. A histogram was constructed, showing the proportion of the number of stems that fell in each of the six log-basal area classes.

A logarithmic frequency distribution was calculated for 197 80-yr-old trees at Cooley Mountain (Fig. 8). The logarithmic transformation means that the basal area limits of each class are 1.59 times those of the next smaller class (Table 2). The log-basal area distribution of the Cooley Mountain stands approaches the log-normal form, but is skewed toward the larger size classes. The histogram of the Malay Gap stands is similar in shape (Fig. 8). By contrast, the log-basal area histogram of the 1903-1914 Maverick and Bog Creek stands is somewhat skewed toward the smaller size classes. The younger stands from the same area show an even greater relative preponderance of trees in the smaller size classes (Fig. 9).

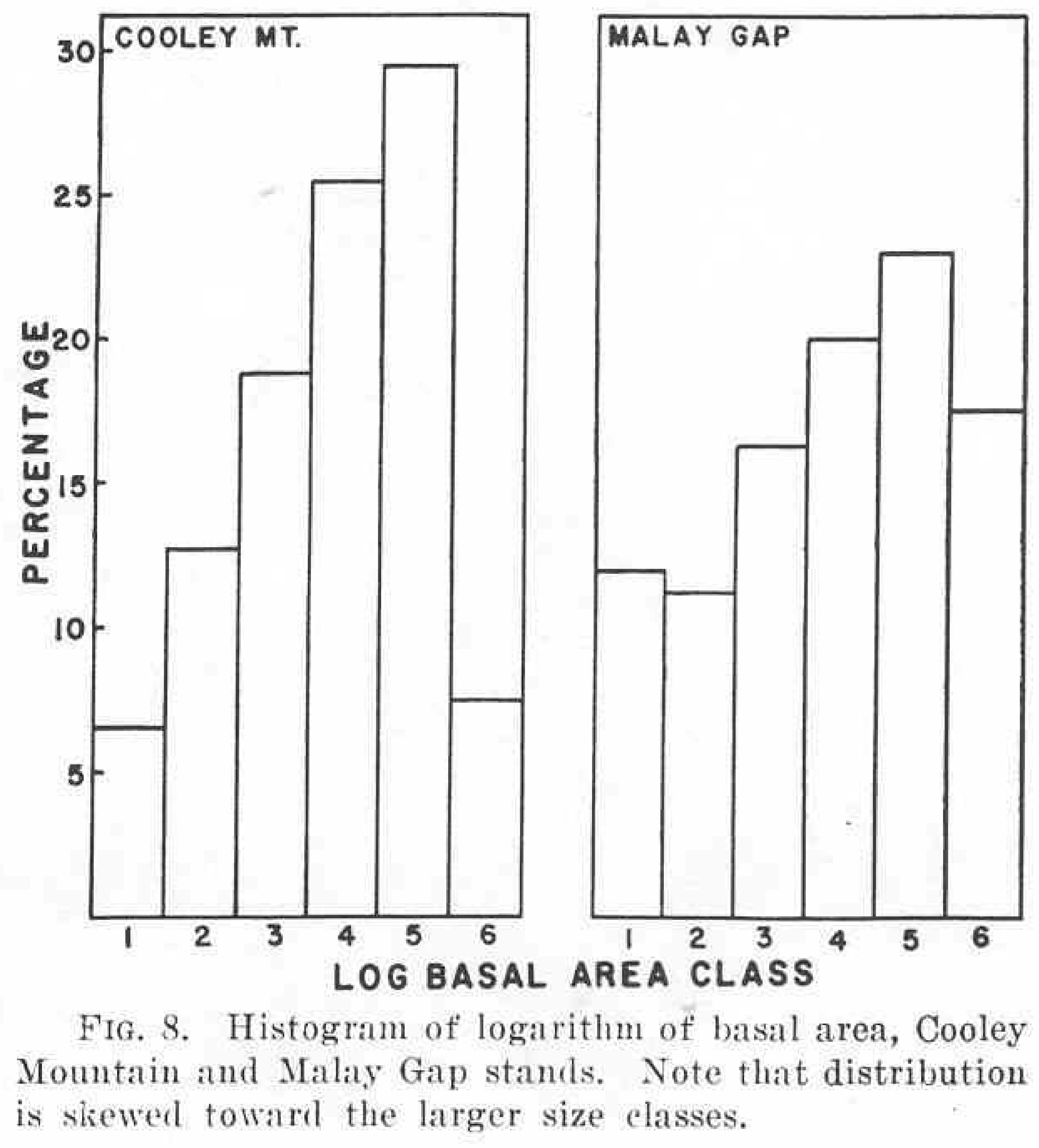


FIG. 8. Histogram of logarithm of basal area, Cooley Mountain and Malay Gap stands. Note that distribution is skewed toward the larger size classes.

### AGE CLASSES OF REPRODUCTION STANDS

Only in occasional years of favorable weather can reproduction become established. The 1919 year class is conspicuous throughout Arizona, particularly around Flagstaff. It is present in the Bog Creek area, but is almost completely lacking further south at Maverick. Possible reasons for the lack of this important age class will be discussed later. Other

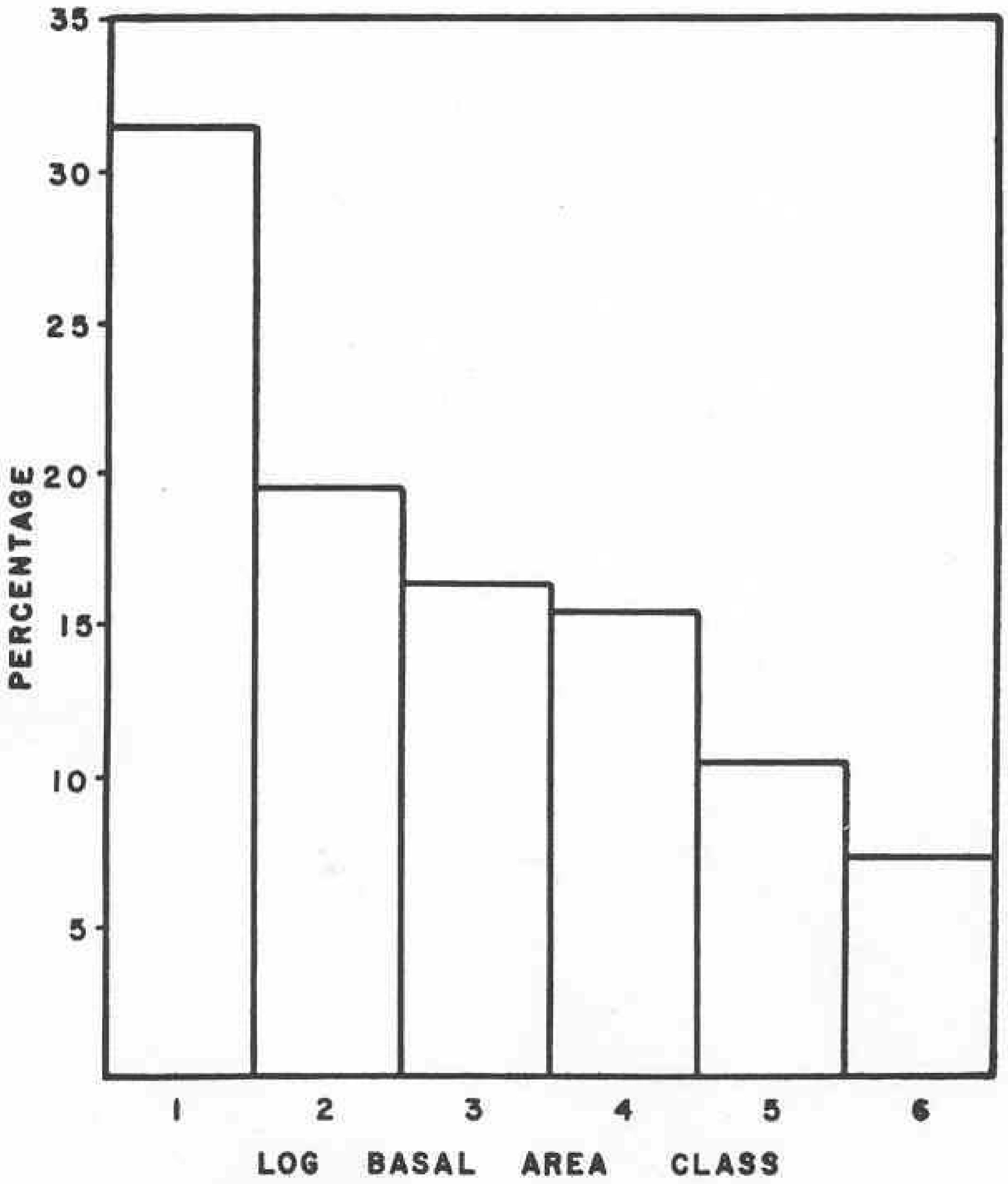


FIG. 9. Histogram of logarithm of basal area, Maverick stands never exposed to fire. Distribution is skewed toward smaller trees.

TABLE 2. Calculation of class interval for frequency distribution, Cooley Mountain.

| | D.b.h. | Log basal area |
|---|---|---|
| Largest tree.......... | 21.4 | 0.39759 |
| Smallest tree.......... | 5.3 | 9.18526 − 10 |
| Difference............ | | 1.21233 |

Class interval = 1.21233 ÷ 6 = 0.20205
Antilog 0.20205 = 1.592 = class multiplier

classes recognizable in one or more of the areas studied are 1903, 1909, 1923, and 1928. A few small stands at Bog Creek originated in 1933. Trees of other ages are rare, and there are no extensive stands of saplings less than 25 yrs old. In part this is because there is little room in the densely stocked old-growth forest for young trees—the available space has been pre-empted by the heavy growth of earlier years. It is evident, though, that weather conditions in the White Mountains have not been suitable in recent years for the establishment of ponderosa pine reproduction.

### RELATION OF MEAN GROWTH PER TREE TO STOCKING

At moderate stocking rates in young stands of ponderosa pine, mean growth per tree is evidently a function of available growing space and, perhaps, of the age of the stand. Age of stand, however, makes little difference in the amount of stem growth added at Maverick and Bog Creek. The stem area growth on each plot during the decade 1948-1957 was compared with the growth on the same plot in the previous ten-year period. A t-test applied to these paired comparisons showed no statistically significant difference in growth in the two periods; the computed value of t was less than one. At least in the age range from about 20 yrs to 55 yrs, the amount of stem area growth added by any one stand remains relatively constant from one decade to the next.

A linear regression equation can be closely fitted to the mean growth per tree of the Maverick-Bog Creek stands, if stands of extremely high and low density are omitted from the calculation. Based upon 25 stands supporting from 480 to 7700 stems per A,

$$g = 0.00309 + 52.6 \frac{1}{n} \qquad (2)$$

where g is mean stem area growth per tree in 10 yrs, expressed in square feet, and n is number of trees per acre. Each individual observation used in the calculation of this regression was weighted by the reciprocal of stand density. This reciprocal is of course the same as available space per tree. The resulting equation accounts for about 92% of the observed variance in mean growth.

Stands with more than 7700 stems per A were omitted from this calculation because it was evident from the graph of the data that average growth of very dense stands deviated from a straight line. To demonstrate this fact, deviations from regression were computed for each of the 25 stands used in the original calculation, and also for the 6 overstocked stands omitted from the regression (Fig. 10). It is clear that as stand density exceeded about 6000 stems per A, growth deviated more and more from the calculated straight line. This point marked the beginning of stagnation.

There is certainly a minimum stocking rate below which growth per tree no longer increases. When the available space per tree exceeds that which the average tree can properly exploit, a further increase

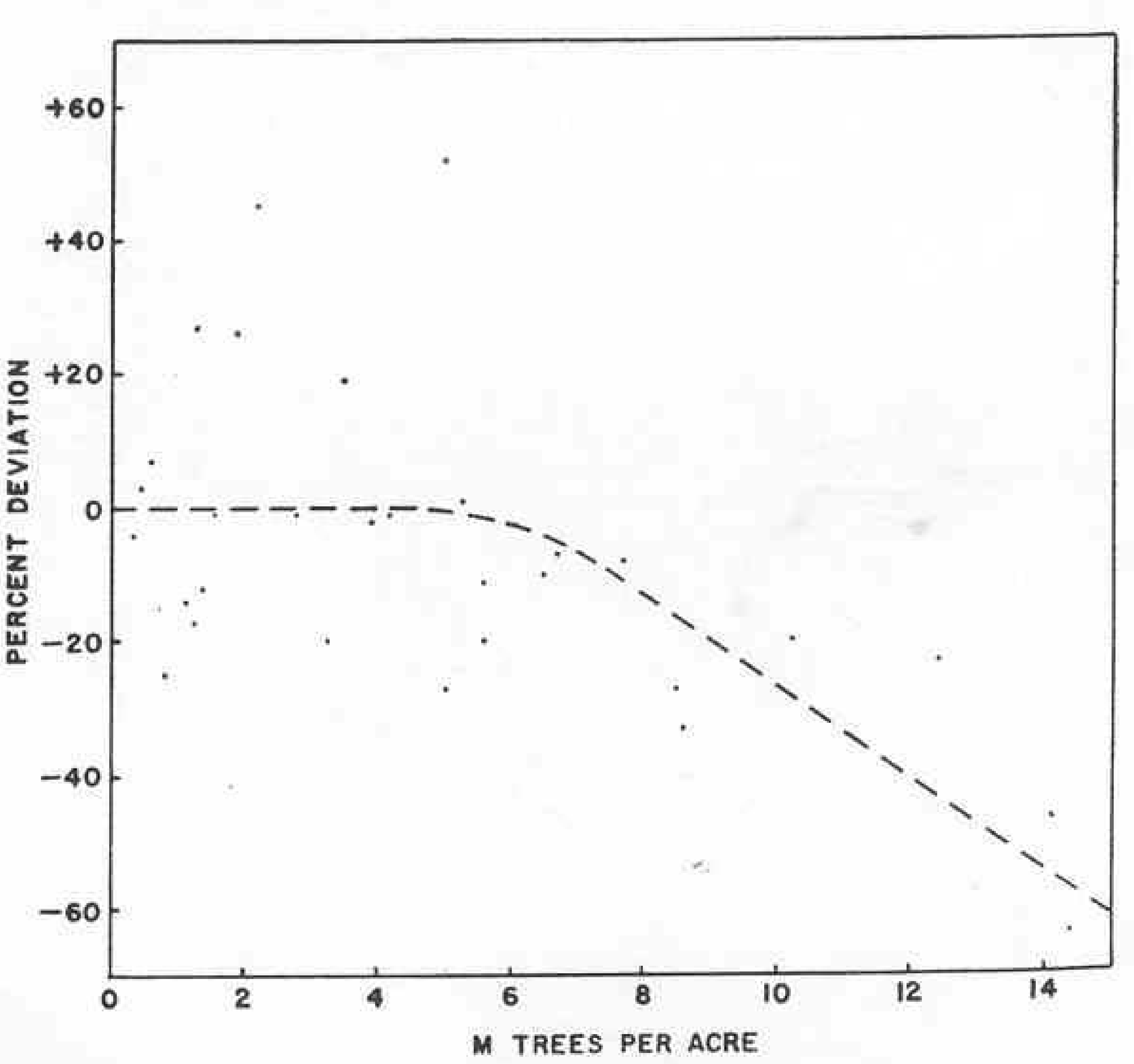


FIG. 10. Percentage deviations from regression equation relating mean growth per tree to stand density.

in spacing will yield no appreciable additional growth. Too few stands of very low density were included in this study to give much information on this point. It seems, though, that a decrease in stand density below about 450 stems per acre in 35-yr-old stands does not greatly stimulate growth.

Increment cores from several thrifty open-grown trees were used to estimate maximum growth rates in the absence of competition. Although mean growth per tree in moderately stocked stands remains relatively constant from one decade to the next, stem area growth of open-grown trees is directly proportional to age. Based on 39 observations,

$$g_0 = 0.0100 \ t \qquad (3)$$

where $g_0$ is 10-yr growth in square feet and t is age at the midpoint of the growth period. It is apparent from plotting of the data that the range or spread of the observed growth values increases directly with age, so that the standard deviation of growth is directly proportional to age, and its variance to the square of age. It is therefore appropriate in the fitting of equation (3) to weight each observation by the square of age. The standard deviation of the resulting regression coefficient is 0.008.

A tentative idea of the maximum space that can be utilized by a single tree can be obtained by combining equations (2) and (3). The average age of the trees used in the calculation of (2) is 40 yrs, so that the age at midpoint of the 10-yr growth period is 35 yrs. It follows from the two equations that a spacing of about 150 trees per A in a 35-yr-old stand should yield the same growth per tree as that obtained from open-grown trees of the same age. Of course, trees in such an open stand would probably be of poor form and quality.

## TOTAL STEM GROWTH PER ACRE

Total periodic growth per acre is closely related to stocking rate, but the form of the relationship is more complex than that of individual tree growth. Total stem area growth increases with stand density up to a point, and then decreases as number of trees per acre exceeds the optimum. A simple graph of stem area growth over stand density best demonstrates this relationship (Fig. 11). Growth increases rapidly with stand density up to about 4000 stems per acre, and then decreases slowly as stocking rate continues to increase. The curve is similar in shape to that shown by Gaines (1951) for longleaf pine. As in longleaf pine, growth of ponderosa pine stands is more closely related to number of trees per acre than to stand basal area.

The total basal area per acre is determined both by the number of trees per acre and by the age of the stand. Since basal area is a joint function of stand age and density, it is best visualized by plotting basal area over the product of number of trees per acre times age (nt). The resulting curve has its maximum at nt = 160,000 (Fig. 12). Substituting various values of t and solving gives an indication of the stand density that will produce the maximum basal area per acre at any given age (Fig. 13). According to this estimate, maximum basal area will be reached with about 6400 trees per A at 25 yrs, and with about 3200 at 50 yrs.

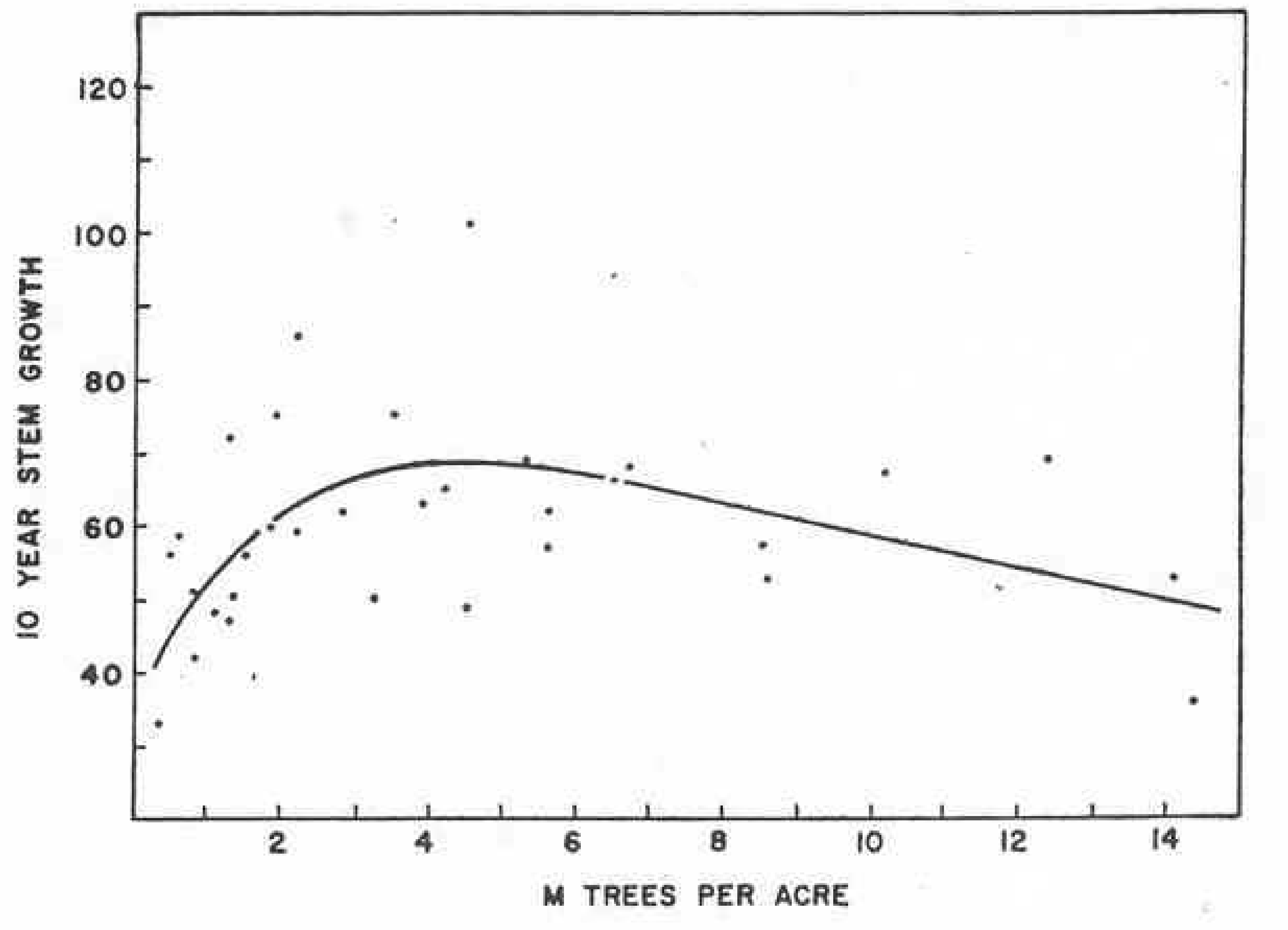


FIG. 11. Stem area growth in square feet per A in 10 yrs as a function of stand density.

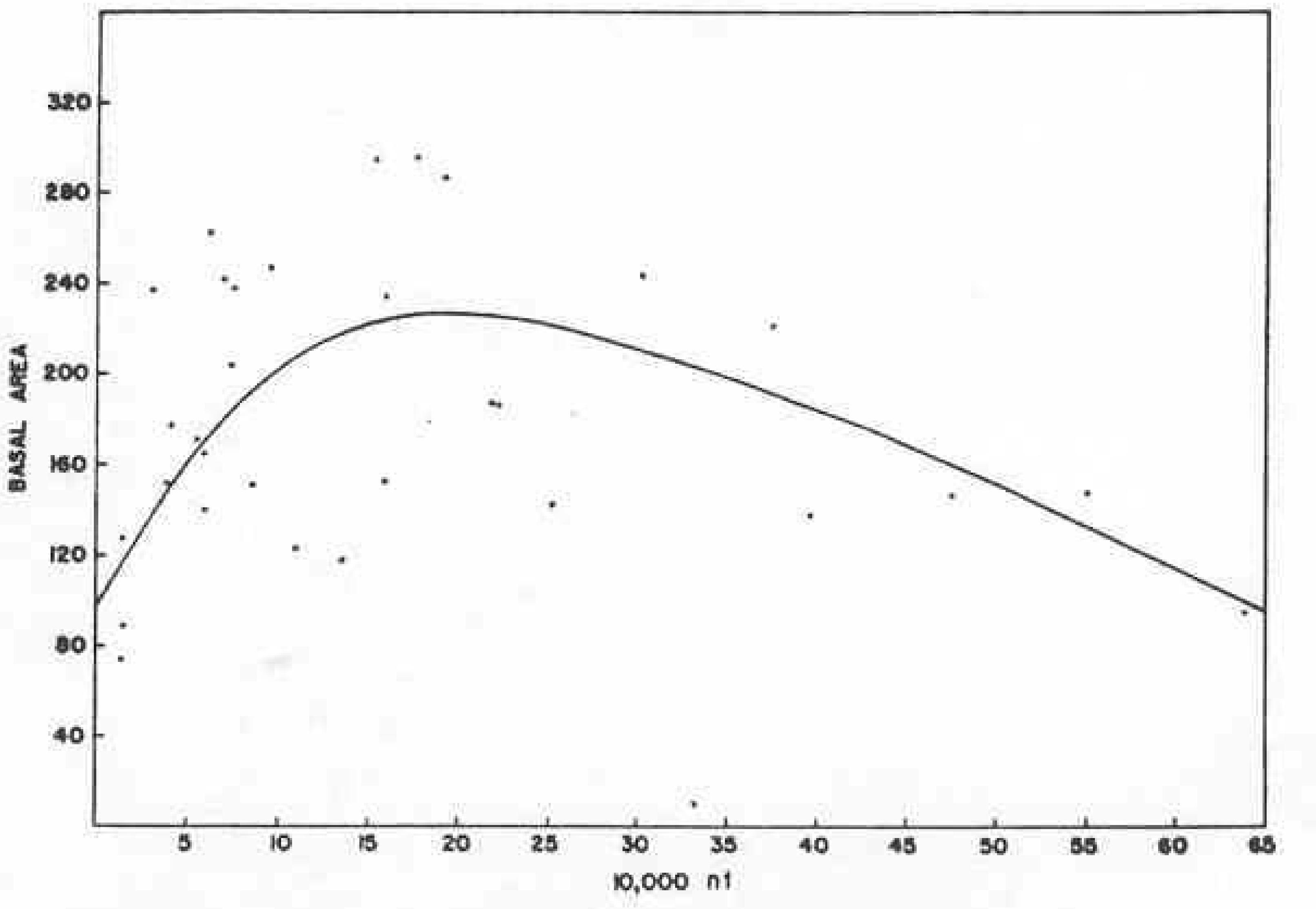


FIG. 12. Total basal area per acre as determined jointly by number of trees per acre (n) and by age of stand (t). Basal area is plotted over the product of trees per acre times age (nt).

The maximum basal area attained by these young stands is far in excess of the 100 sq ft per A that Pearson (1950) considered to represent full stocking. According to the Maverick timber inventory, average basal area on good sites is slightly more than 100 sq ft per A. This figure integrates mature groups, young thickets, and small openings. In small, uniform pole stands, basal area can easily reach more than twice Pearson's full stocking estimate.

## DOMINANCE, SUPPRESSION, AND MORTALITY

The preceding growth studies have dealt with all trees in the stand, small as well as large. It is generally considered that the smaller trees in a stand, however, have little effect on the growth of the dominants. It has been almost universally accepted that as the dominant trees grow up and overtop the smaller, the losers in the competitive race are suppressed, retarded in their growth, and eventually

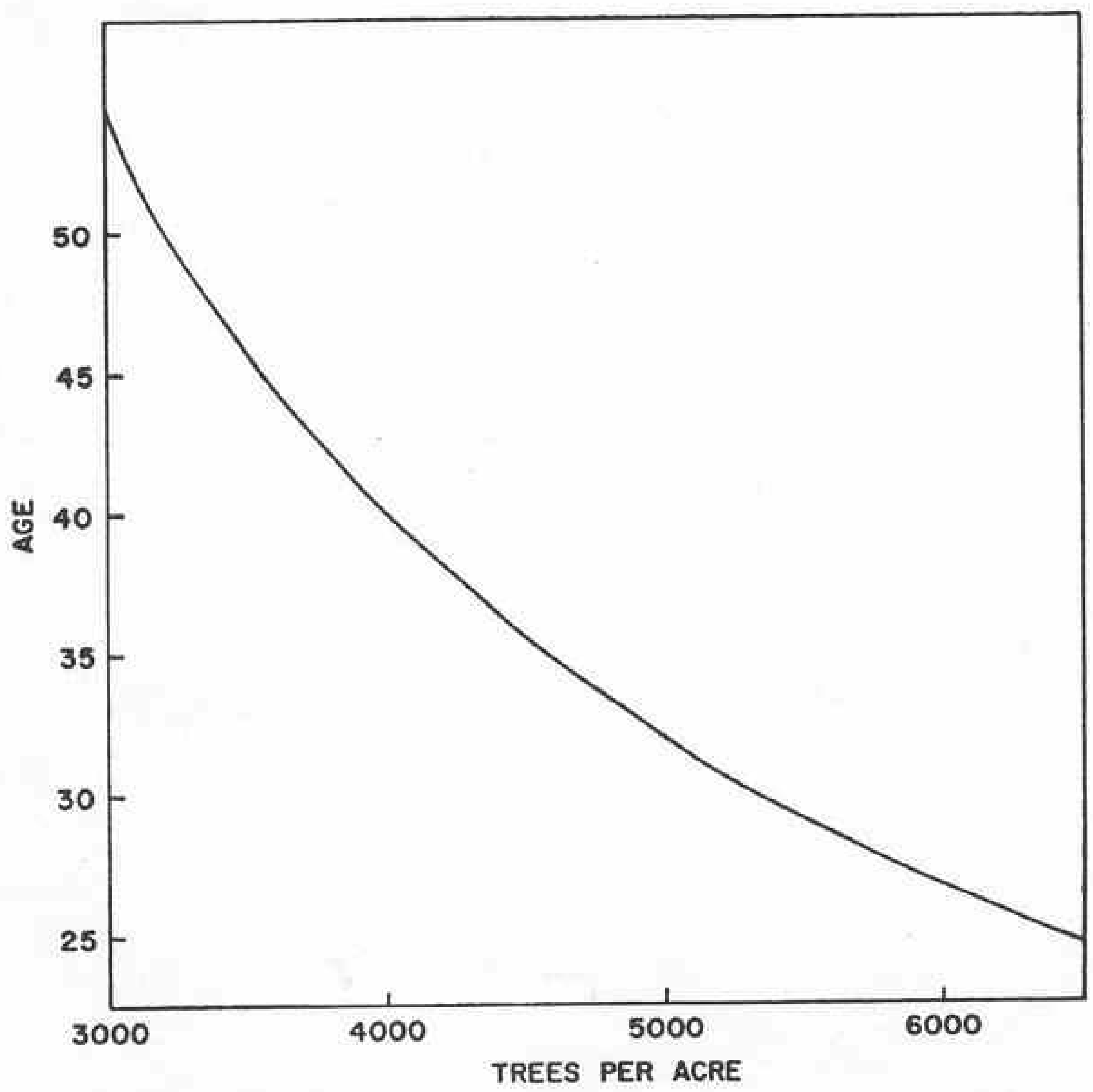


FIG. 13. Stand density at Maverick that is predicted to yield the maximum basal area at various ages.

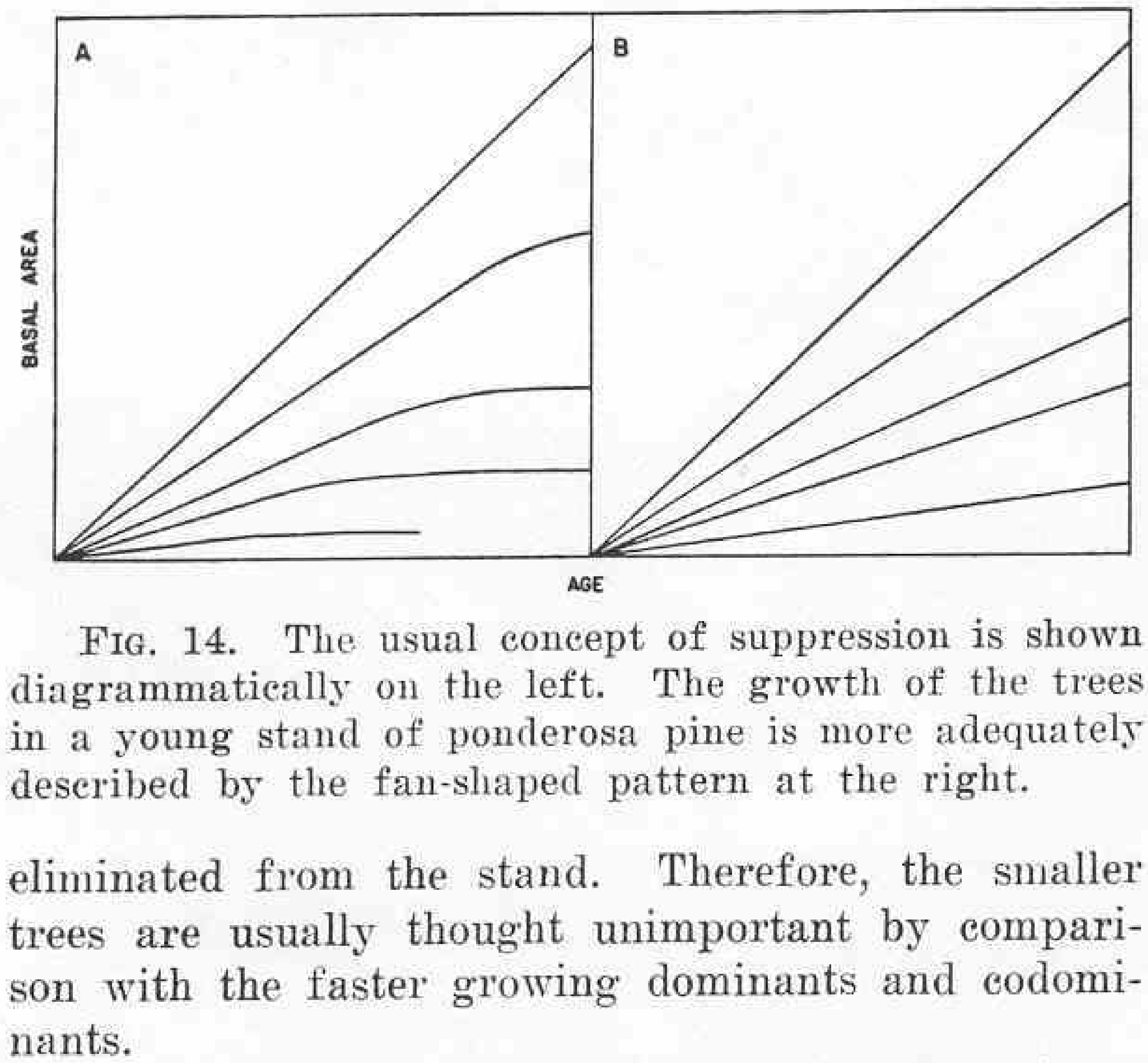


FIG. 14. The usual concept of suppression is shown diagrammatically on the left. The growth of the trees in a young stand of ponderosa pine is more adequately described by the fan-shaped pattern at the right.

eliminated from the stand. Therefore, the smaller trees are usually thought unimportant by comparison with the faster growing dominants and codominants.

This description of the suppression process is no doubt valid in those forests where the primary competition is for light. It does not, however, hold true in the ponderosa pine forests of the Southwest, where competition is mostly for water. As Pearson (1950) has pointed out, sunlight is much less likely to limit growth of ponderosa pine than is water supply. In the forests of the humid regions, once a tree is overtopped it becomes successively less able to secure the light energy needed for growth; hence it is suppressed and its growth nearly ceases. Where light is abundant and water is lacking, however, even small trees are usually able to secure their small but proportionate share of available soil moisture, so that the growth of small trees is not much retarded even by apparent suppression.

Small ponderosa pines grow slowly from a very early age, their growth increment remaining nearly constant from one period to the next. Basal area of large trees likewise increases rather uniformly in successive periods. The growth of the trees comprising a stand of ponderosa pine more nearly resembles the fan-shaped pattern of Figure 14b than the more usual suppression pattern of Figure 14a.

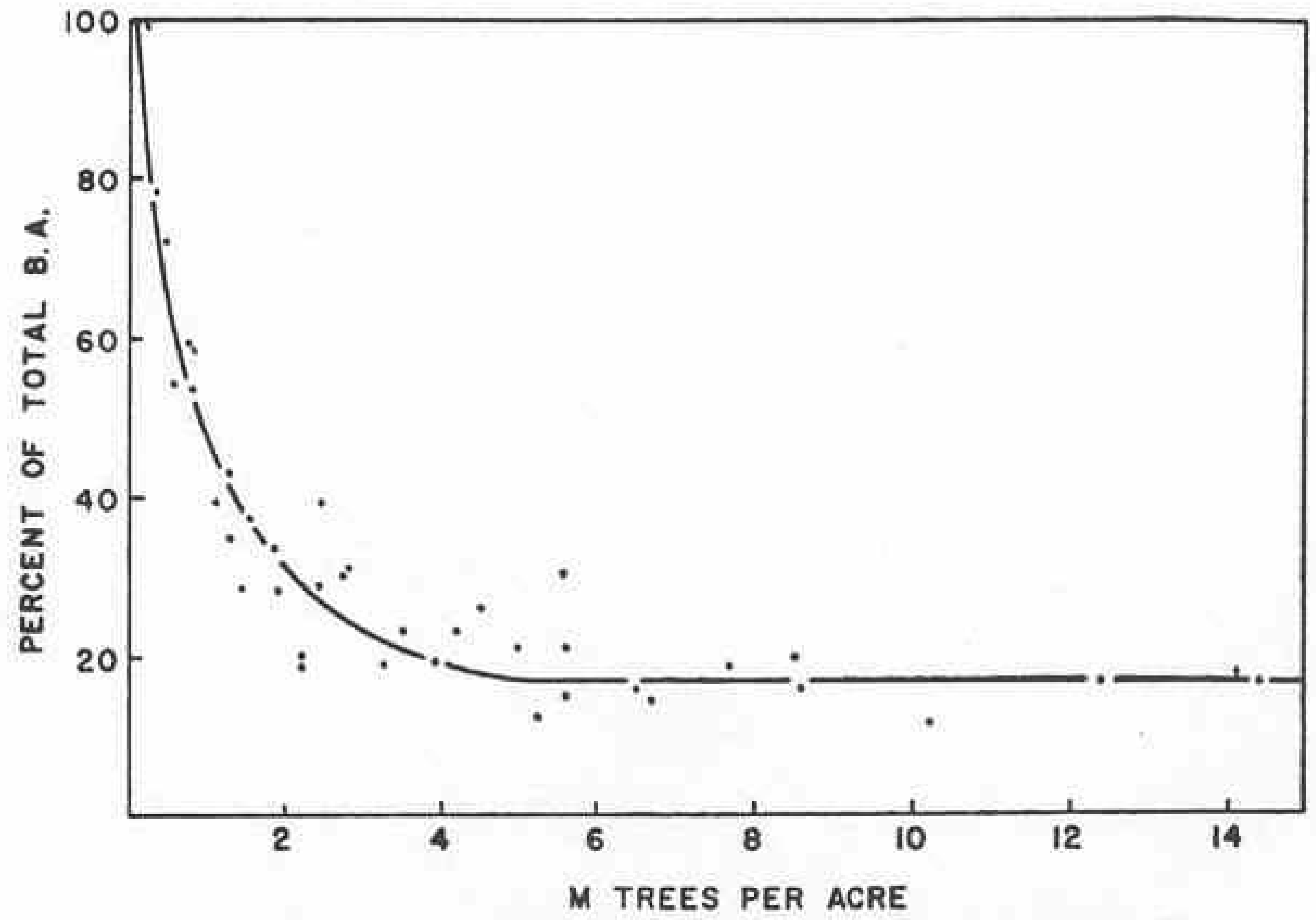


FIG. 15. Proportion of the total stand basal area contributed by the 400 largest trees per A in stands of varying density.

A statistical comparison of the growth of the smallest trees on a single plot with that of the largest trees on the same plot provides evidence of this growth pattern. Data for the 5 largest and the 5 smallest trees on a sample plot bearing 21 trees were used for this comparison. Stem areas in 1957, 1947, 1937, and 1927 were grouped for each set, and the resulting relationship tested for linearity of regression by a method suggested by Snedecor (1956:455). In neither the large trees nor the small ones was the departure from linearity greater than would be expected from chance variation alone (Table 3).

TABLE 3. Analysis of variance, linearity of growth of dominant and suppressed trees.

| Source | 5 LARGEST TREES | | 5 SMALLEST TREES | |
|---|---|---|---|---|
| | D.F. | Mean Square | D.F. | Mean Square |
| Linear regression | 1 | 9018.73 | 1 | 17.3556 |
| Deviations from linearity | 2 | 1.20 | 2 | .0240 |
| Error | 16 | 289.20 | 16 | .8809 |

Suppressed and intermediate trees evidently play a greater role in young ponderosa pine stands than is customarily attributed to small trees. The proportion of total stand basal area contributed by the smaller trees increases with stand density (Fig. 15). At low stocking rates, virtually all the basal area of a stand is contained in the 400 largest trees on each acre. The proportion of the total contributed by these larger trees declines as density increases, until with more than 5000 stems per A only about 17% of the basal area is due to the 400 largest trees. Approximately the same relationship applies to total

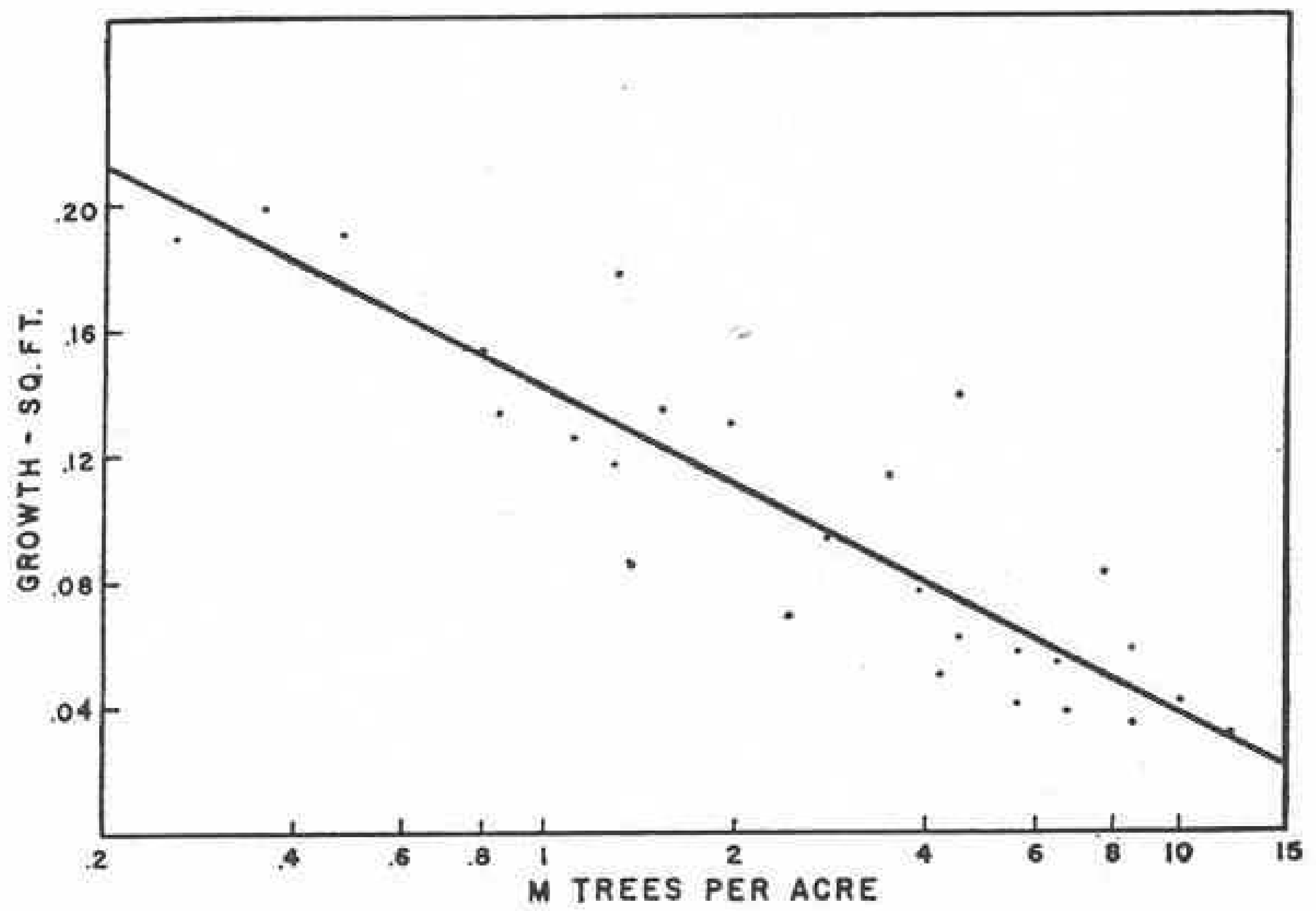


FIG. 16. Growth of the largest trees in each stand as a function of stocking.

periodic growth. The larger trees, which are often the only ones considered in growth analysis, add considerably less to total stand growth in young dense stands than do the great mass of small trees. The relative importance in stand growth and use of available water, nutrients, and light by any single tree in young ponderosa pine stands is roughly proportional to its size. This is unlike the situation in more humid forests where suppressed trees exert less influence on growth of dominant trees even than their dimensions would imply.

Concern has been expressed, by Weaver (1951a) and others, that the use of soil moisture by developing pine thickets may adversely affect the growth of the mature pine overstory. Several mature pines, more or less isolated within dense sapling stands, were examined at Bog Creek for evidence of this effect. Mature trees with poor crowns (e.g., Keen tree classes 3C, 3D, and 4C) could be expected to be most affected by competition from the sapling understory. Increment borings from 6 such trees showed no unmistakable evidence of a change in growth pattern since origin of the sapling stands. Growth before and after that time was so slow as to be almost imperceptible. It may be, however, that the decline of these decadent trees was hastened by sapling competition.

In contrast to these results, Weaver (1959) has reported that on the Warm Springs Indian Reservation in Oregon, thrifty mature trees of Keen class 3B not subjected to understory competition grew 23% faster than their counterparts within dense sapling thickets. Competition from the understory affected immature pines of Keen class 2B even more strikingly.

Natural mortality in dense young ponderosa pine stands is surprisingly low, even among clearly suppressed trees. Examination of fire-killed trees of known age established that it is easily possible to identify every tree larger than 0.5 in. d.b.h. that has died within the past 6 yrs. On all the sample plots in reproduction stands, a tally of dead trees was kept (Table 4). Natural mortality of small suppressed trees less than one inch in diameter probably does not exceed 2% annually; in the larger size classes it is much less. The uncertainty derives from the fact that there is no way of knowing how many years' accumulation of dead trees is included in the mortality tally. The figure of 6 yrs is no more than a guess. In this area of slow decay, identifiable dead trees may last even longer.

TABLE 4. Estimated natural mortality in last six years on sample plots.

| | Diameter Class | | | | | |
|---|---|---|---|---|---|---|
| | Less than 1″ | 1.0-1.9″ | 2.0-2.9″ | 3.0-3.9″ | 4.0-5.9″ | 6.0-7.9″ |
| Number of dead trees per acre... | 470 | 184 | 31 | 16 | 8 | 2 |
| Mortality as % of number in size class 6 years ago. | 6.7% | 4.0% | 1.1% | 0.8% | 0.6% | 0.7% |

GROWTH OF POTENTIAL CROP TREES

The largest trees in the stand will comprise most of the dominant mature stand and will make up most of the eventual timber harvest in managed stands. It is of interest to consider the relationship of the growth of these dominants to stand density.

Growth of the largest trees in each stand is more closely related to the logarithm of stand density than to its reciprocal or to other measures used in the preceding analyses (Fig. 16). Measurements of trees on 27 sample plots show that for the 400 largest trees per A

$$g_L = 0.34 - 0.10 \log n \qquad (4)$$

where $g_L$ is mean stem growth per tree per decade in square feet, and n is number of stems per acre. The standard deviation of the regression coefficient is 0.033; the computed regression accounts for about 79% of the observed variance in mean growth of the largest trees.

GROWTH AND NEEDLE WEIGHT OF INDIVIDUAL TREES

Cable (1958) has shown that there is a logarithmic relationship between needle weight and diameter of individual mature ponderosa pine trees in central Arizona. The relationship of stem area growth to needle weight in young pine stands was investigated on two of the 1/100 A sample plots at Maverick.

All trees were cut on these two plots, and the current year's crop of needles stripped from each tree. Sampling was done in early November after seasonal growth was completed. Needles were air-dried with the aid of a steam radiator, since no oven facilities were available. Stem area growth during the preceding ten-year period was determined from stump sections as before. The trees on one plot were about 49 yrs old; the other plot was aged 30 yrs. The 18 trees on the older plot ranged from 1.0 to 8.8 in. d.b.h.; the 24 on the younger plot were from 0.5 to 7.3 in. d.b.h.

Stem area growth on these two plots is directly proportional to needle weight, according to the equation

$$g = 0.00624\ W \qquad (5)$$

where g is 10-yr stem area growth of a tree in square feet and W is weight of the current year's needles in kilograms. There is no statistically significant difference in the regression equations applicable to the two stands despite their difference in age; hence the data from all 42 trees were pooled in the calculation of the final regression equation.

The direct relationship between needle weight and tree growth is to be expected, for needle weight is a measure of the quantity of photosynthetic tissue available for the elaboration of material to be stored as new wood. There is a definite difference in the weight of the current year's needles on the two plots: 1063 kg per A in the older stand, and 787 kg in the younger. An estimate based on only two trees suggests that about 40% of the green needles present in November, after needle fall is mostly completed, are of the current year's crop.

### HEIGHT OF DOMINANTS AS A FUNCTION OF AGE AND STOCKING

Foresters have usually considered that height of the dominant trees of a given species varies much less with stand density than do tree diameters; hence height of dominants in relation to age is frequently used as a measure of site quality. Lynch (1958) has pointed out that in many instances height growth is very markedly affected by stand density. He concluded from a review of the literature that retardation of height growth by density of stocking is most apparent where root competition is most intense. Lynch went on to evaluate the effect of stocking rates on height of dominants in ponderosa pine stands in Washington and Idaho. He represented density of stocking as a proportion of the average density calculated from all his plot data. He found that tree heights are reduced as stocking percentage exceeds 100, and that the effect of stand density on height is much greater on poor sites than on good.

Lynch's method of relating height growth to stand density is not applicable to the present study, partly at least because the average stocking rate calculated from all the sample plots would still represent a generally overstocked condition. Instead, the mean height of the two tallest trees on each plot was considered as a function of stand age and stocking rate. For the 29 plots at Maverick and Bog Creek for which height measurements were available,

$$H = 100 - 18.8 \log n - 7.66 \frac{1}{t} \qquad (6)$$

where H is height of dominants in feet, n is number of trees per acre, and t is age of stand in years. This equation accounts for 86% of the variance in height. If extrapolated far beyond the range of the data from which it was derived, this equation indicates that the maximum attainable height of ponderosa pine trees at Maverick is 100 ft. Actually, fully mature dominants reach a height of about 110 ft.

## PATTERN

A conspicuous feature of the ponderosa pine forest is the grouped arrangement of the trees. It is obvious that the forest is composed of distinct groups, each made up of several trees similar in size and apparent age (Fig. 17). This fact has long been recognized, but surprisingly little attention has been given to the structure of these groups or to their mode of origin.

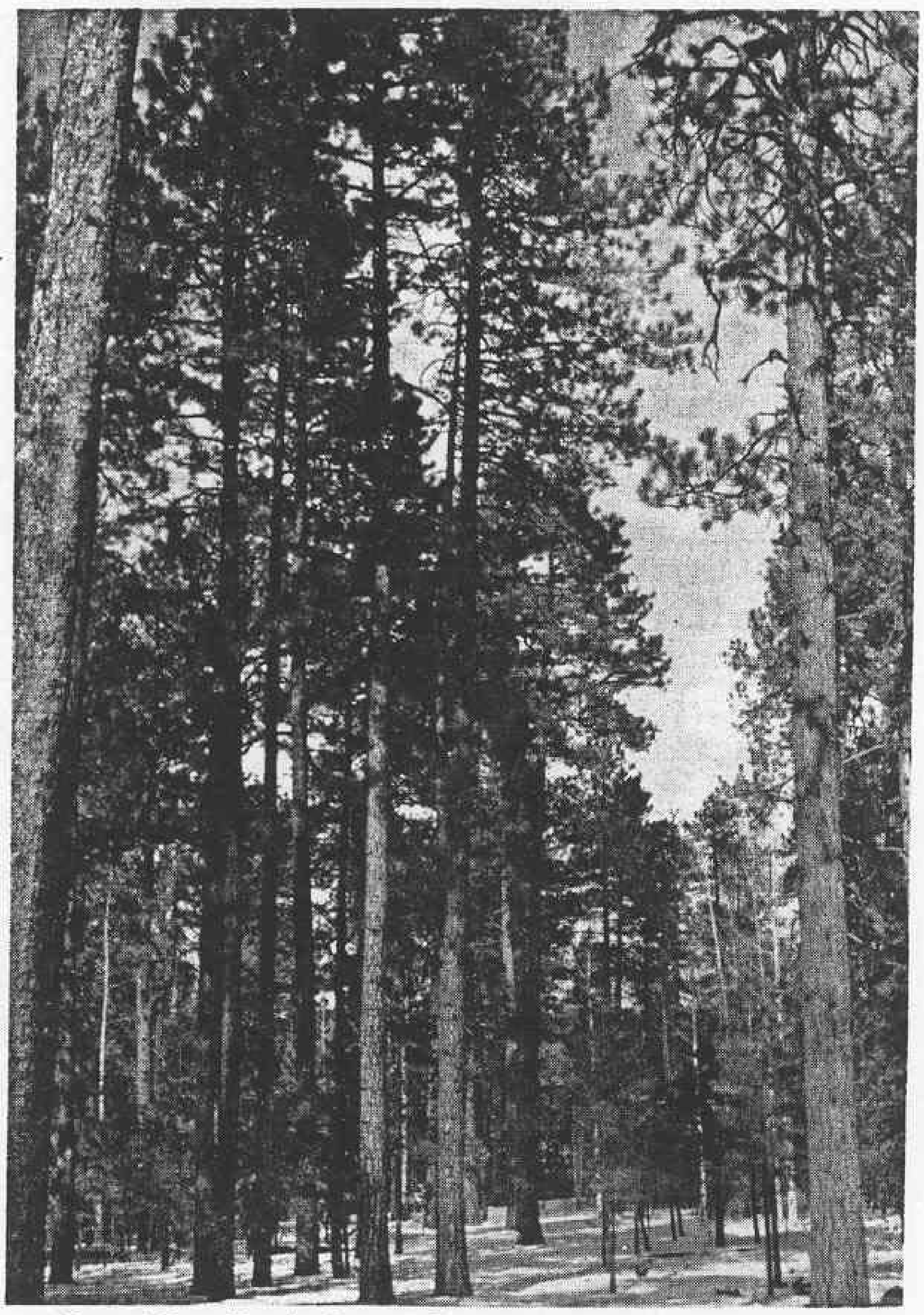

FIG. 17. Typical stand of mature ponderosa pine, showing grouped distribution of trees.

An objective stand analysis technique is offered by the method of contiguous quadrats proposed by Grieg-Smith (1952). He suggested laying out a grid of 256 contiguous quadrats, and recording the number of plants falling in each. In analysis of the data, each pair of adjacent quadrats is combined, creating what amounts to a new grid of 128 blocks on the same area. The combining procedure is repeated several times to give the number of individuals per block when the blocks consist of 1, 2, 4, 8, 16, 32, 64, and 128 of the original small quadrat units. An analysis of variance is then carried out to determine the variance (mean square) attributable to each of these

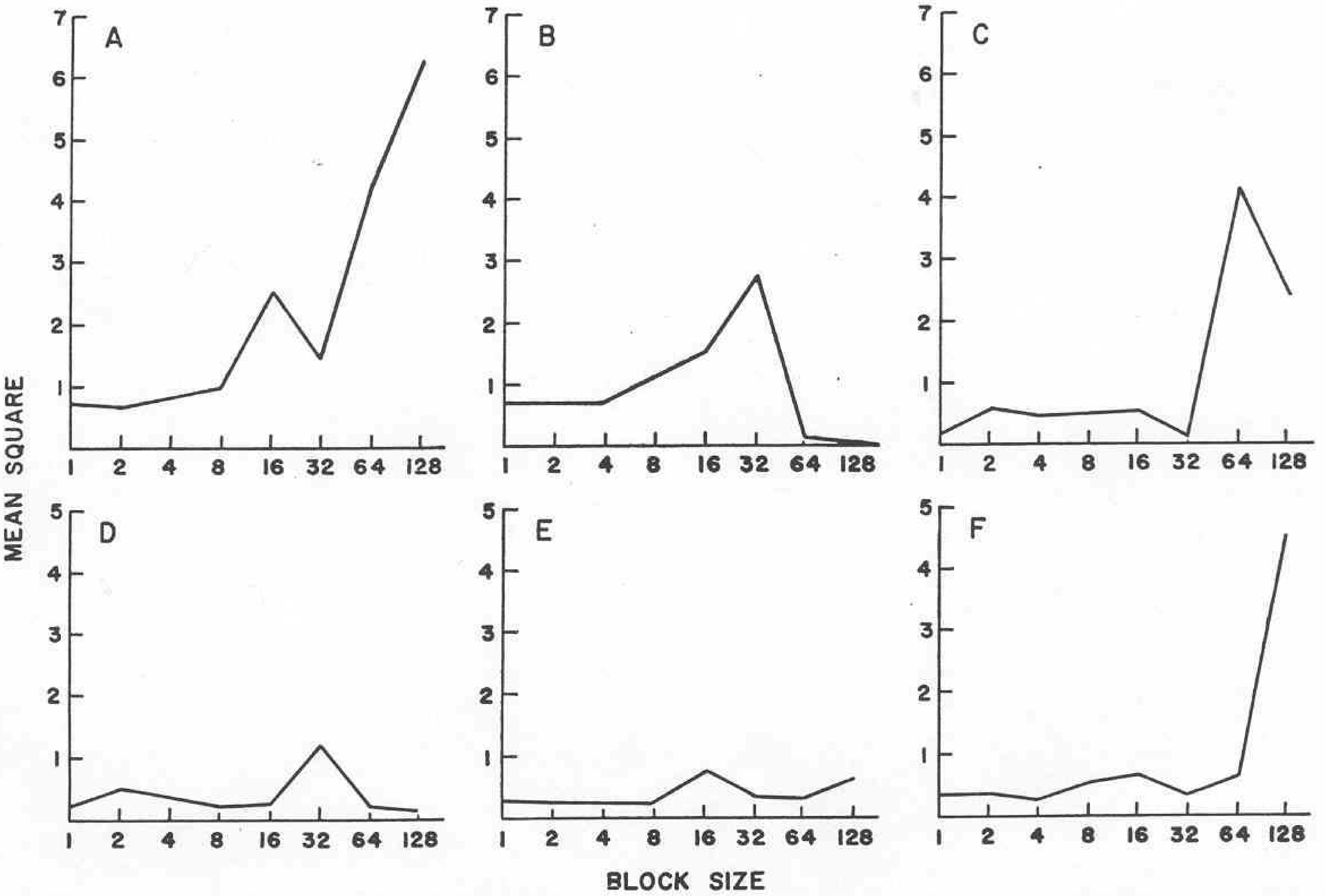


FIG. 18. Variance (mean square) attributable to blocks of different size, contiguous quadrat analysis of mature stand at Malay Gap (A, B) and at Maverick (C, D, E, F).

block sizes. If the vegetation forms a distinctly clumped pattern, the variance of the block size corresponding to the approximate mean area of the clump will be much higher than the variance due to other block sizes.

Testing of the significance of the variance for the various block sizes presents considerable difficulty. Grieg-Smith originally suggested using a variance ratio test to compare the mean square due to various block sizes with the mean square residual for single quadrats. Once the fact of non-randomness of vegetation is established, however, a variance ratio test is no longer appropriate. At the present stage of development of contiguous quadrat analysis, conclusions are best based on a subjective interpretation of peaks in variance. The consistent recurrence of a peak at about the same block size in a series of analyses gives a strong indication of its validity (Thompson 1958).

The theory underlying contiguous quadrat analysis assumes that the area of the plant is negligible in relation to the size of the quadrat. This is clearly not true in ponderosa pine. The use of 1/100 A quadrats, however, makes plot size rather large in relation to all but the largest trees.

Four grids of 256 contiguous 1/100 A quadrats were set up at Maverick, and two at Malay Gap. The largest block size was thus 2.56 A. In analyzing the pattern of the mature stand, only trees evidently older than 50 yrs were considered. Most of the six grids show a pronounced peak in variance at block sizes of 16 or 32 quadrats (Fig. 18). Several of the grids also show a high variance at the largest block size. Little significance can be attached to the latter peaks because of the small number of degrees of freedom upon which they are based. There is only one degree of freedom associated with a block size of 128 quadrats, and two with the next smaller block size. The large variances at the bigger block sizes may be due to chance alone, or they may be associated with a larger scale pattern of vegetation.

Contiguous quadrat analysis indicates that the trees comprising the mature stand at both Maverick and Malay Gap are aggregated into groups with an area of .16 to .32 A. This is consistent with what has already been observed about the clumped distribution cf ponderosa pine.

A similar analysis was made of the reproduction stand on the same six 2.56 A plots. It seemed inadvisable, because of the great difference in size of individuals, to combine both the mature stand and young trees in a single computation. All trees over 2 in. d.b.h. were included in the reproduction tally (Fig. 19). As in the mature stand, the Malay Gap grids show a pronounced peak at a block size of 16 to 32 quadrat units. The average clump size of young trees at Malay Gap is about .16 to .32 A.

The Maverick grids show an evident peak at about the same block size as at Malay Gap. The main peak, however, is at 64 quadrat units, reflecting the

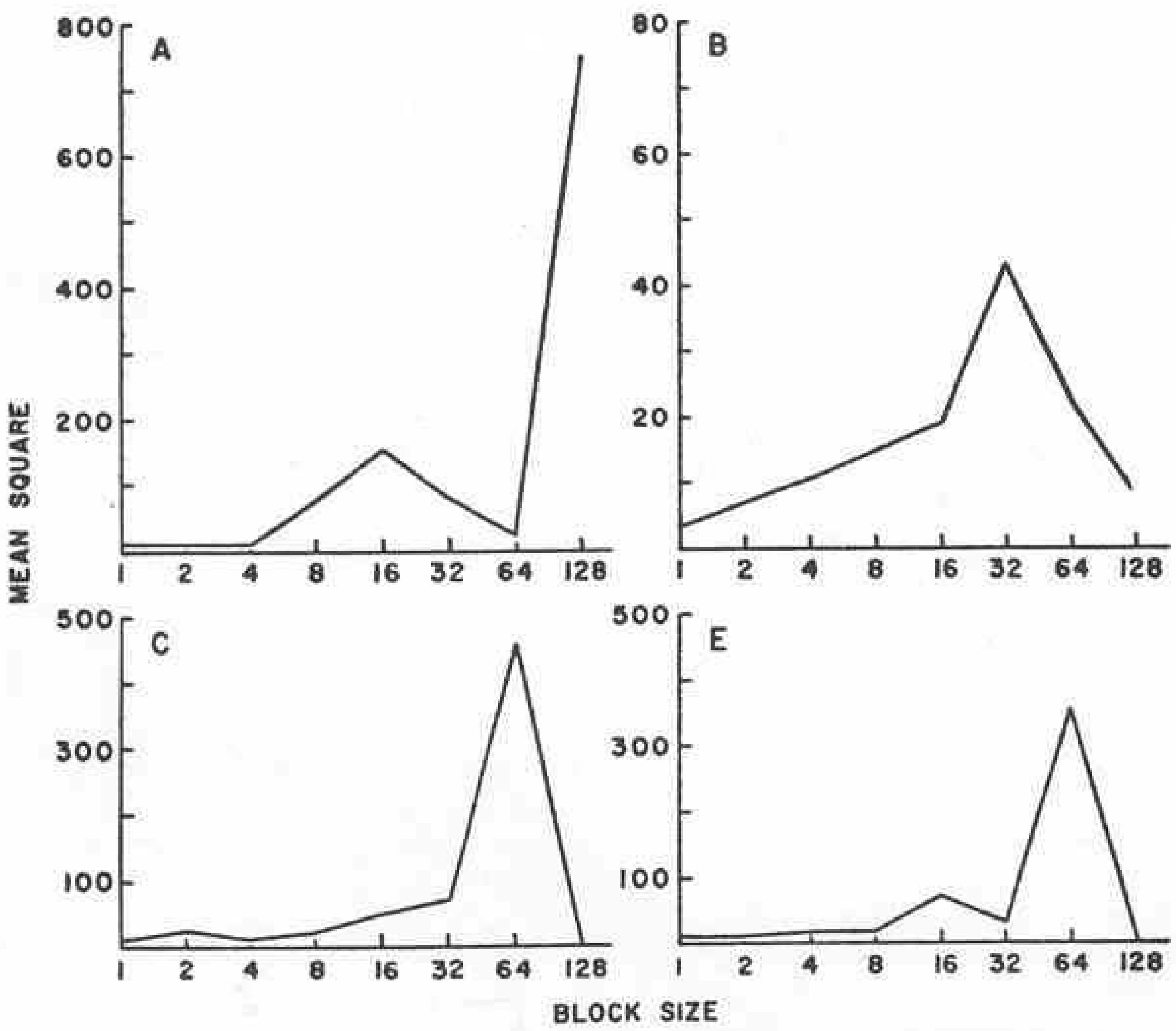


FIG. 19. Variance (mean square) attributable to blocks of different size, contiguous quadrat analysis of reproduction stand at Malay Gap (A, B) and at Maverick (C, E).

large patches of reproduction that are clearly evident at Maverick. Within these large patches are smaller clumps of thriftier and more vigorous trees. The smaller sub-groups are indicated by the peaks at 16 and 32 units.

## FOREST CONDITIONS AT MAVERICK AND AT MALAY GAP

Although similar in basic composition and structure, the forests at Maverick and at Malay Gap are quite different in appearance. A visitor to Malay Gap, conditioned by acquaintance with the over-dense thickets characteristic of most of the Southwestern pine region, is immediately struck by the open nature of the forest (Fig. 20). The forest floor is carpeted with a deep layer of grass, and small discrete patches of young trees are dispersed among groups of stately pines. The pure beauty of the Malay Gap region more than compensates for its difficulty of access.

FIG. 20. Typical view of the ponderosa pine forest in the primitive area at Malay Gap.

The site at Malay Gap is clearly not as good as that at Maverick. The average height of mature dominants at Malay Gap is about 95 ft, while those at Maverick average about 110 ft. The height of dominants in sapling stands averages 10 to 12 ft less than in stands of comparable age and stocking density at Maverick. According to the Malay Gap timber inventory, the average basal area of the mature stand is about 70 sq ft per A on the most densely stocked 8200 A. By contrast, the mean basal area of the 13,000 A timber type including all the Maverick study plots is about 102 square feet per acre. The difference reflects inherent differences in site productivity.

Until recently, lack of adequate transportation has prevented an effective fire control program at Malay Gap. Weaver (1951a) found from analysis of fire scars that fires had swept across Malay Gap in 1943, 1935, 1919, 1910, and about every 7 yrs before that time. Fire scars on living trees indicate that at least the last two fires were very extensive and covered most of the area. By contrast, the areas studied at Maverick and Bog Creek have either been free of fire since stand origin, or have been protected since a fire in 1924. Differences in site quality and in fire history are the primary differences between Maverick and Malay Gap. To determine how each of these factors has affected stand structure, it is necessary to examine some of the ecological effects of fire in ponderosa pine.

## FIRE IN THE ECOLOGY OF PONDEROSA PINE

A number of recent studies on the relation of fire to ponderosa pine have been reported by Harold Weaver. On the Colville Indian Reservation in eastern Washington, he examined a group of 40-yr-old pine stands. One portion of the study area was burned by a wildfire in September, 1914, when the young pines were about 11 yrs old; the other portion had been protected from fire throughout its life. Thirty years later, the unburned area was covered by a stagnated stand of saplings so thick in places as to be almost impenetrable. There was an average of 14,800 stems per A on plots in the unburned area, with a mean d.b.h. of 1.7 inches and a height of 12.3 ft. Stand density in the stocked portion of the fire-thinned area was 1100 stems per A, the trees averaging 7.4 in. in diameter and 32.2 ft in height. Only about 9% of the burned area was stocked, the result of a hot fire burning out of control (Weaver 1947). In the Southwest, exclusion of fire has likewise induced the formation of dense thickets which give every impression of near stagnation (Weaver 1951a).

As a consequence of long continued fire exclusion, fire hazard has built up until the stage is set for a devastating conflagration (Weaver 1951a, 1955). The dense reproduction stands are themselves highly inflammable. A heavy needle mat has accumulated, and snags and dead wood have added fuel. Without periodic fires to remove this debris a little at a time, it has built up to a point where any fire is liable to race uncontrolled through the treetops. Weaver believes this increase in fire hazard to be the most potentially dangerous change that has occurred since early days.

In June, 1956, a spark from a logging operation set off a fire that ran out of control through 21,000 A of ponderosa pine forest north of the Mogollon Rim. The behavior of the fire and the meteorological conditions accompanying it were analyzed by Schaefer (1957). He described the Dudley Lake fire as a classic example of a fire accelerated by local air subsidence and a low-level jet current. The hot, dry winds resulting from these unusual conditions lead to an explosive situation in which even the most modern fire fighting equipment is ineffectual once a conflagration gets under way. Yet it is possible to argue that the Dudley Lake fire would not have killed virtually every tree that it touched had not the forest fuel been allowed to accumulate for 40 yrs and more. Surely local air subsidence and jet streams have recurred throughout history, but there is no clear evidence of past holocausts of the magnitude of Dudley Lake in the ponderosa pine forest. The Dudley Lake fire was touched off by logging and not by lightning; but there is no reason to doubt that Indians built campfires in the woods even in the hot, dry days of June.

Preliminary test of prescribed burning in Arizona (Weaver 1952) showed that lighter fuels such as fallen needles, branches, and cones were reduced approximately 55% by weight, while the cubic foot volume of logs and stumps declined 64% to 80%. Four years later, though, the quantity of fuel on the ground equalled that before burning (unpublished data on file at Fort Apache Agency, Whiteriver, Arizona). Part of this increase is attributable to the fact that 30 yrs of fire exclusion prior to the experimental burns had allowed an abnormal number of live needles to remain on the lower portions of the tree crowns. Light fires which do not ignite the crown generally singe the lower needles, which then fall from the tree. The height of the needle scorch resulting from a low intensity fire is a function of the initial vegetation temperature and of the height of the flames above the ground (Byram 1958). Live needles extended to within a few feet of the ground on the Fort Apache experimental burning plots; these needles were singed by the fire, fell to the ground, and added their bulk to the quantity of fuel on the forest floor after the prescribed burn. A second fire might produce a more long-lasting fuel reduction.

This burning experiment evaluated only the effects of fire on dry fuel lying on the ground. Of equal importance is the effect of repeated fires on the hazards represented by sapling stands, which are highly subject to destruction by crown fires. Crown fires are of two types: dependent, which require heat from surface fuels to preheat and ignite the crown, and independent, in which the fire travels directly from crown to crown without aid from surface fuel combustion. Most crown fires observed in the Southwest on relatively level ground are dependent. The likelihood of crown ignition resulting from a surface fire is a function of the height of the base of the crown above the flames. If, for instance, there are no needles below the 12-ft level, the crowns of a sapling stand are much less likely to be ignited by a surface fire than if the crown level is at a height of 6 ft. The quantitative effects on fire spread and severity of the raising of crown level are not known, but they are evidently considerable. It is well known that the intensity of radiated heat varies as the square of the distance from the source. In a surface fire in a sapling stand, though, this relation is greatly complicated by heat convection.

If a crown fire should start in a sapling stand, it is not apt to run as far or as fast if some of the fuel has been removed as in a solid stand of dense saplings. Experience on the Fort Apache Reservation has demonstrated that it is easier to fight a wildfire in an area previously treated with controlled fire than in untreated areas. In summary, long continued fire exclusion has increased the danger of destructive wildfires in three ways: by permitting excessive buildup of dry fuel on the forest floor, by leaving the tree crown level near the ground where ignition of live needles is more likely, and by permitting the formation of dense uninterrupted sapling stands over wide areas.

## STAND STRUCTURE AT MAVERICK AND AT MALAY GAP

The young trees at Malay Gap are arranged much more definitely in groups than at Maverick, and only rarely do they grow under or very close to the trees of the mature stand. On only 10 of 512 quadrats were young trees more than one inch in diameter found growing on the same 1/100 A plot as a mature tree. By contrast, 84 out of 1024 similar quadrats at Maverick had reproduction and mature trees growing on the same plot. The association of mature trees with young trees was tested for both stands, using a chi-square test on a 2 by 2 contingency table. Chi-square values for both the Maverick and the Malay Gap tables were highly significant, indicating a strong tendency for reproduction and mature trees not to be associated on the same quadrat. Chi-square values were much larger, however, for the Malay Gap tables than for the Maverick data. Only trees larger than 1 in. d.b.h. were considered in this analysis. There are many stunted and suppressed trees 2 to 6 ft tall growing under the mature overstory at Maverick. Most of these trees are at least 20 yrs old, and some are more than 30. Trees of this type are almost totally lacking under the Malay Gap overstory.

The lack of trees under the mature stand is evidently the result both of competition and of the periodic fires that have swept the Malay Gap area. Even under the open canopy of a mature forest, seedlings grow poorly (Fig. 21). Though the trees remain alive, they are stunted and unhealthy. Root competition, rather than competition for light, is apparently the governing factor. Root grafts between adjacent trees of the mature stand may play a part, although there seem to have been no studies of this subject in ponderosa pine. Yli-Vakkuri (1954) found that in even-aged stands of Scotch pine in Finland, many middle-aged trees had root grafts with the root systems of neighboring trees. Sometimes a network of

10 or more trees is formed by grafting, and water and nutrients are transferred through grafts from one tree to another. It is possible that there is a similar interconnection of the root systems of a mature even-aged group of ponderosa pines. If so, the united root systems may ramify so completely through the soil that newly established trees are unable to compete effectively.

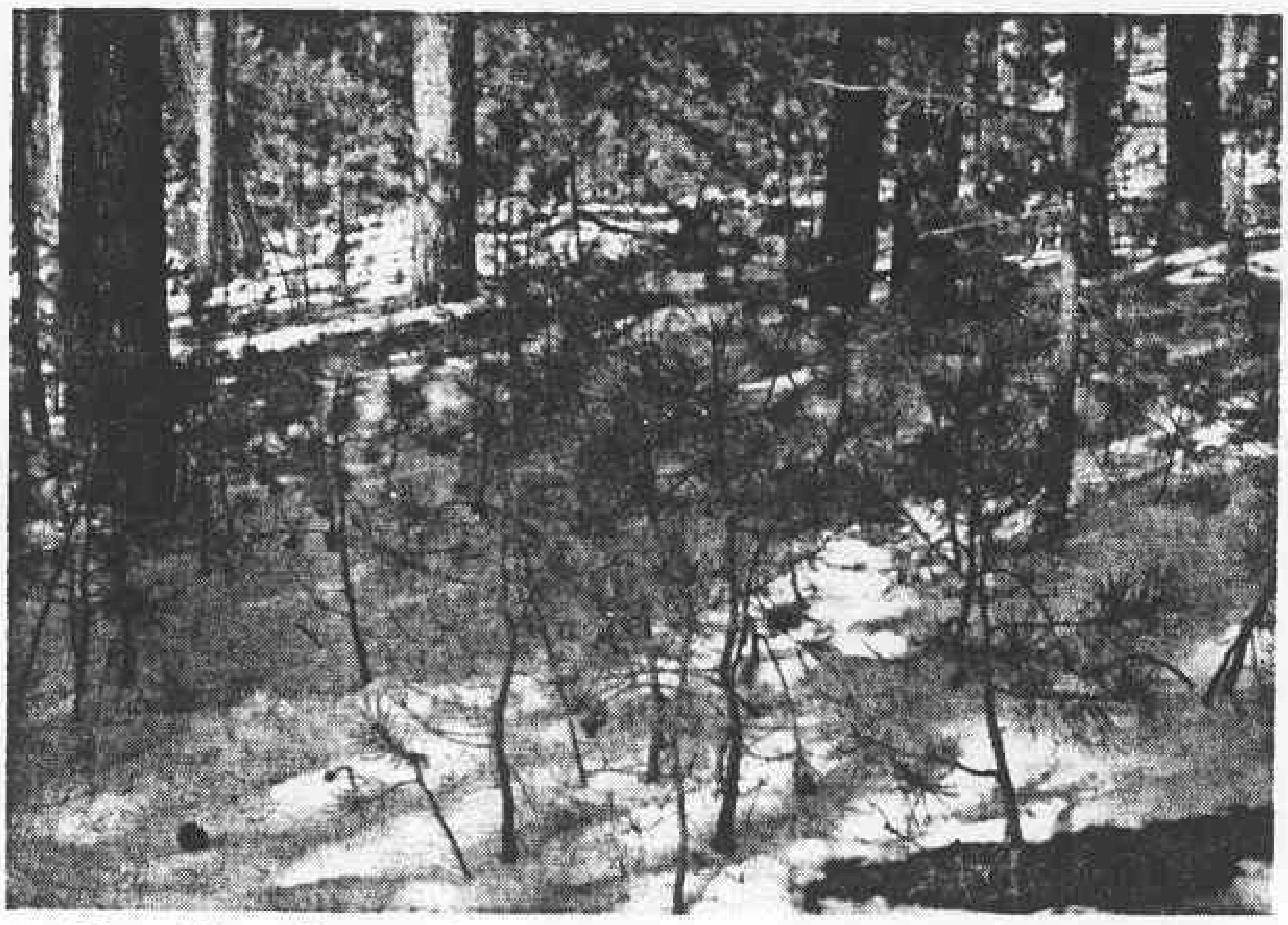

FIG. 21. Stunted trees, 18 yrs old, growing under a mature group of pines at Maverick. Tallest of these trees is less than 3 ft high.

When a light surface fire passes through the forest, the stunted trees growing beneath the pine overstory are too small and weak to withstand its effects. A fire intensity that would injure a thrifty sapling little if at all is often fatal to a suppressed tree of the same age. More important, though, is the effect of needle fall from the mature stand. A considerable volume of light fuel rapidly builds up beneath the mature stand. When ignited, this fuel generates enough heat to kill any young trees which may be growing in its midst. By contrast, the lesser fuel accumulation in openings makes a less intense fire which saplings are able to survive. Evidence for this differential removal of trees under the forest canopy is provided by many observations on the controlled burns on the Fort Apache Indian Reservation. Virtually every seedling and sapling beneath mature trees is killed by the controlled burns, while nearby reproduction stands remain almost intact.

The failure of reproduction to survive under the mature canopy in the presence of fire largely accounts for the difference in pattern of smaller trees between Maverick and Malay Gap. Contiguous quadrat analysis demonstrated the existence of definite reproduction groups, .16 to .32 A in size, at Malay Gap. At Maverick, on the other hand, stunted reproduction is widespread beneath the mature trees, becoming much more vigorous in the openings (Fig. 22). This accounts for the peaks at two block sizes in the mean square diagram of Figure 18.

It has been asserted that the small trees growing under the mature overstory represent valuable advance reproduction which will greatly speed up stand regeneration following timber harvest. Actually, it

FIG. 22. Typical stand at Maverick, protected from fire since 1924.

is doubtful if these stunted trees will respond to release at all. Establishment of seedlings some 6 or 8 yrs before cutting the mature trees, if possible, is almost certainly good forest practice, but the stunted little trees 20 and 30 yrs old that often grow in the shade of the mature stand are probably more of a hindrance than a help to future forest growth.

There are many more trees per acre, particularly in the smaller size classes, at Maverick than at Malay Gap. On the 2.56 A plots at Maverick, there are almost twice as many trees in each of the size classes from 1 to 8 in. d.b.h. as on comparable plots at Malay Gap (Table 5). The numbers of trees larger than 9 in. are much more nearly equal on the two sets of plots, the slightly larger number at Maverick closely reflecting better site quality.

TABLE 5. Number of trees per acre in diameter classes from 1 to 14 in. on sample plots at Maverick and Malay Gap.

| d.b.h. | TREES PER ACRE | |
|---|---|---|
| | Maverick | Malay Gap |
| 1 | 241 | 110 |
| 2 | 141 | 83 |
| 3 | 79 | 46 |
| 4 | 61 | 38 |
| 5 | 26 | 10 |
| 6 | 18 | 6.2 |
| 7 | 9.3 | 3.6 |
| 8 | 7.0 | 2.8 |
| 9 | 4.4 | 4.4 |
| 10 | 2.1 | 1.4 |
| 11 | 1.7 | 3.0 |
| 12 | 1.9 | 3.6 |
| 13 | 2.2 | 3.0 |
| 14 | 1.4 | 2.4 |

Although the small plots in reproduction stands were not intended as a quantitative estimate of stand density on the area as a whole, it is significant that the average number of trees per acre on the Maverick-Bog Creek plots is two to four times as great as on plots of comparable age at Malay Gap (Table 6). It has already been pointed out that the Maverick

TABLE 6. Summary of sample plots in reproduction stands

| Location | Year of Origin | No. of Plots | STEMS PER ACRE BY DIAMETER CLASS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Less than 1″ | 1.0-1.9″ | 2.0-2.9″ | 3.0-3.9″ | 4.0-5.9″ | 6.0-7.9″ | Over 8.0″ | Total |
| Bog Creek | 1919 | 8 | 4280 | 2257 | 1102 | 623 | 422 | 63 | | 8748 |
| Maverick | 1928 | 9 | 1522 | 1353 | 604 | 471 | 369 | 47 | | 4367 |
| Malay Gap | 1914-19 | 13 | 332 | 400 | 605 | 488 | 355 | 115 | 15 | 2311 |
| Malay Gap | 1928 | 8 | 435 | 400 | 415 | 335 | 265 | 60 | | 1910 |

and Bog Creek plots have a much higher proportion of small trees than those from Malay Gap. The Malay Gap plots have the most trees in the largest size class, despite the definitely poorer site.

The densest stand sampled at Bog Creek had the equivalent of 14,400 stems per A in a 38-yr-old stand. The average density of seven 1919 stands at Bog Creek was almost 9000 stems per A. This figure is probably more or less representative of the mean density of pine thickets in the White Mountains. A series of twelve 2.5-A plots established in connection with the Fort Apache controlled burning program carried an average of 4855 trees less than 3.5 in. d.b.h. per A (unpublished data on file at Fort Apache Agency, Whiteriver, Arizona). These 12 plots were in a stand of ponderosa pine logged in 1924, and included the usual mixture of openings, reserved tree groups, and pine thickets common to cutover areas. It is likely that stand density on that part of these plots actually stocked with reproduction would approach the 9000 per A found on the Bog Creek plots.

Sapling stands of 1919 age support more trees per acre than do younger plots that would normally be expected to carry more trees (Table 6). Evidently conditions in later years did not permit as high a percentage of seedling survival as in 1919. At any rate, the average stand density on 9 sample plots in 1928 stands at Bog Creek is 4867 trees per A, about half that on the 1919 plots.

## FIRE EFFECTS ON SAPLING STANDS

Much of the difference between the virgin area and the managed forest is due to the fires that have continued at Malay Gap. Natural surface fires have long been a part of the environment of the pine forest. What has been the role of these natural fires in the development of the forest? Equally important, what has been the effect on stand structure of forty years and more of fire exclusion?

A partial answer to these questions might be offered by an analysis of the results of the Fort Apache controlled burning program, but these burns have been carried out in stands that are no longer normal. Forty years of complete protection from fire have permitted the development of thickets with an abnormal number of trees per acre and an abnormal accumulation of fuel. A surface fire run through such a thicket is much different in its effects than if the stand has been burned at frequent intervals throughout its life.

Other prescribed burning experiments are slightly more informative. A 20-A tract of overstocked ponderosa pine thickets in north-central Washington was treated with controlled fire in 1942, and the results evaluated in 1950 (Morris & Mowat 1958). Future crop trees, those that are likely to constitute the mature stand of the future, were selected on the basis of size and vigor. The crop trees on the burned area grew 36% more in diameter and 7% more in height than those on the unburned plots, while the number of trees that offered significant competition to the selected trees was reduced from 2,410 to 895 per A. The authors concluded that prescribed fire, properly applied, can reduce competition among trees in dense ponderosa pine thickets and increase the growth of potential crop trees. The thinning was not uniform or selective, and occasionally destroyed all saplings in some poorly stocked portions of the stand.

The effects of natural fires on reproduction stands were studied at Malay Gap. Recorded fires have passed through that area at least 3 times in the lifetime of the present sapling stands: in 1919, in 1935, and in 1943. More recently, the B.S. Gap Fire of September, 1956, covered several hundred acres in the same area. This was a moderate surface fire apparently typical of those that have occurred many times in the past. The area burned faced to the north, on about a 15% slope. Weather records from Maverick Lookout, 8 mi northwest at about the same elevation, show that relative humidity was low and temperature high in the days preceding the fire. The fire danger rating, a numerical value that integrates fuel moisture, humidity, temperature, and wind, was almost as high in the three days preceding the fire as at the peak of the spring dry period. The B.S. Gap fire burned under severe, if not extreme, fire hazard conditions.

When the fire area was examined in September, 1957, the scorched needles, although brown and dry, still remained on the trees. It was thus possible to assess the amount of direct damage to tree crowns. Completely dead trees were also easy to detect. Lynch (1959) has reported on a study of mortality following fire in a 30- to 40-yr-old stand of ponderosa pine in eastern Washington. He found that mortality was correlated with degree of crown damage and with tree size. Most of the mortality occurred in the first year following fire, and most of the first-year mortality was caused by crown burning. There was significant mortality the second year as well, mostly due to direct damage to the cambium.

The trees examined after the B.S. Gap fire had gone through only one growing season since the fire. Some additional mortality is to be expected, but the first-year effects will give a strong indication of the action of a natural fire on pine reproduction stands.

A large proportion of the trees less than one inch in diameter was killed by the fire. There were fewer of these small trees to begin with than on comparable plots in the unburned forest at Maverick and Bog Creek, and fewer still survived the 1956 fire. A progressively smaller proportion of trees was killed in each larger diameter class. Only 18% of the very small trees survived, whereas 84% of the stems in the 4- to 6-in. class remained and no trees over 8 in. d.b.h. died on any of the plots in the first year following the fire. No trees larger than 14 in. d.b.h. were observed to have been killed anywhere in the fire area. The first year effect of the B.S. Gap fire on the reproduction stand is expressed by the equation

$$P = 0.61 - 0.66 \log D \qquad (7)$$

where P is the proportion of the total number of trees of a given size killed by the fire, and D is d.b.h. in inches. This equation is of course strictly applicable only to this one fire. While the absolute number of saplings killed may vary from fire to fire, somewhat the same proportionate relationship between size classes can be expected to be maintained.

The B.S. Gap fire removed about one-fourth of the basal area of reproduction stands. The relationship between basal area of 15 sampled stands before and after the fire is

$$B_f = 0.77\ B_o \qquad (8)$$

where $B_f$ is stand basal area one year after the fire and $B_o$ is basal area before the fire. The standard deviation of the regression coefficient is 0.065. The average basal area found from the 15 plots was 96 sq ft per A before the fire and 76 afterwards. Once again, these figures do not purport to represent the average basal area of the forest as a whole, but rather that of homogeneous clumps of reproduction.

The 1943 fire at Malay Gap reduced several representative sapling stands to a total basal area of 40 to 80 sq ft per A, as revealed by analysis of stump sections. Fourteen years later the basal area of each of these stands had approximately doubled.

### MECHANISM OF THINNING BY FIRE

The differential killing of the smaller stems by fire constitutes a fairly effective thinning from below, which removes many of the small trees that lose out in the race for dominance. In the absence of fire, suppressed saplings tend to hang on and on, each taking at least a small portion of soil moisture at the expense of the dominants.

Natural fires thin sapling stands in three ways. Occasionally the surface fire becomes so hot at the base of a tree that the cambium is killed and the tree girdled. As far as could be told from a superficial field examination, none of the trees on the B.S. Gap fire plots were killed in this way. A certain amount of mortality from this cause may be expected in the second year, however (Lynch 1959).

A second and much more common effect is the thinning of stands by the raising of their crown level. On most of the burned plots at Malay Gap there was a definite zone of scorched needles killed by the heat of the surface fire. Above the scorch line there was little if any needle damage. Obviously, if a suppressed sapling is 10 ft tall and a surface fire kills all needles below the 12-ft level, the small sapling's chances of survival are slim indeed. Most natural fires occur at a season when active growth is taking place, or at least when bud dormancy is not fully established. Under these conditions, heat generally kills buds as well as foliage.

On 10 of the 15 burned plots there was a noticeable raising of the crown level. In one stand with an average height of 27 ft, a crown level formerly at a height of 16 ft was raised to 24 ft. On the other plots, a smaller proportion of the live crown was scorched.

The periodic raising of the crown level and the killing of lower branches by fire aids in the natural pruning of ponderosa pine. This species prunes itself rather poorly, and lower branches tend to remain alive even in dense stands. Fire may be an important agent in the production of clean-boled trees, not so much by actual combustion of lower branches as by killing them so they fall naturally.

A third form of thinning is the killing of trees by the heat of a fiercely burning log or stump. The trees for several feet in every direction are frequently killed and small openings formed in this way. Such openings are seldom large enough to be detrimental to the growth of the stand. Roots of the surrounding trees quickly appropriate the vacant soil space and growth of the remaining trees may be stimulated.

Only rarely will local crowning of a general surface fire destroy a whole patch of young trees. On the B.S. Gap fire no stands were found that had been completely killed, although some were thinned too severely. There is evidence elsewhere at Malay Gap, however, of a number of apparently thrifty reproduction stands that have been totally wiped out, evidently by the fire of 1943.

It seems clear that a fire can and does pass through an established reproduction stand without destroying it. How, though, is it possible for a stand to become established in the face of repeated fires? Seedlings a foot or two high are extremely sensitive to fire, and even up to a height of six feet or more, it is doubtful if a young tree can withstand a surface fire of normal intensity.

Apparently they do not have to. In the normal forest there are many openings in which seedlings become established. There is little accumulation of pine needles or other dry material to carry a fire through these openings. The seedling stand itself does not produce enough dry material to carry a sur-

TABLE 7. Stems per 1/100 acre before and after controlled burning in young stand, Horse Mesa.

| Plot No. | Age at Time of Fire | Height Class at Time of Fire | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <1′ | | 1-2′ | | 2-3′ | | 3-4′ | | 4-5′ | | 5-6′ | | 6-7′ | | 7-8′ | | Total | |
| | | Pre-Burn | Post Burn | Pre-Burn | Post Burn | Pre-Burn | Post Burn | Pre-Burn | Post Burn | Pre-Burn | Post Burn | Pre-Burn | Post Burn | Purn Bre- | Purn Bost | Pre-Burn | Post Burn | Pre-Burn | Post Burn |
| 1. . . . . . . . . . . . . . . . | 11 | 18 | 9 | 40 | 11 | 51 | 24 | 22 | 11 | 4 | 4 | | | | | | | 135 | 59 |
| 2. . . . . . . . . . . . . . . . | 11 | 0 | 0 | 17 | 0 | 29 | 10 | 18 | 10 | 11 | 6 | 1 | 1 | 1 | 1 | | | 78 | 28 |
| 3. . . . . . . . . . . . . . . . | 11 | 16 | 4 | 1 | 1 | 2 | 1 | 6 | 5 | | | 2 | 2 | | | 1 | 1 | 28 | 14 |
| 4. . . . . . . . . . . . . . . . | 11 | 1 | 0 | 6 | 1 | 8 | 6 | 9 | 5 | 11 | 8 | 5 | 5 | 6 | 4 | | | 46 | 29 |
| 5*. . . . . . . . . . . . . . . . | 5 | | | 2 | | 5 | | 7 | | 2 | | 3 | | 1 | | | | 20 | |
| 6*. . . . . . . . . . . . . . . . | 11 | 4 | | 8 | | 21 | | | | | | | | | | | | 33 | |

* Not burned.

face fire until it is about 8 yrs old. Even then, there is usually only enough fuel to support a light and spotty fire.

Evidence for this hypothesis is hard to find because of the scarcity of very young pine stands. There are almost no extensive stands of waist-high trees suitable either for experimental burning or for observations of the results of past burns, except for a few small patches on Horse Mesa, east of Whiteriver.

Horse Mesa was treated with controlled fire in the fall of 1954, 3 yrs before the examination. Six 1/100 A plots were examined (Table 7). Trees on 5 plots were 11 yrs old at the time of the fire, and on one they were 5 yrs of age. The 5-yr-old stand and one of the 11-yr-old stands were not touched at all, even though the fire reached to within 50 to 100 ft in every direction. The obvious reason was lack of sufficient fuel. There was not much grass in the shade of the little trees, and they had dropped few dry needles. The slight fuel accumulation under the other 11-yr-old stands was sufficient to support only a relatively cool fire. This fire eliminated a greater proportion of the stems on the more densely stocked plots than on those that were more open, but the trees killed were mostly in the smaller size classes. The denser stands evidently produced a greater volume of needles which generated a locally hotter fire than that in the more open stands. The least dense of the 11-yr-old sample plots had so little fuel on the ground that fire did not spread to it at all. Any thinning would have left this plot seriously understocked.

Intensity of fire in very young stands sems to be sort of self-regulating feedback mechanism that provides the needed degree of thinning. Where there are many trees per acre, the volume of dry fuel builds up faster and to greater quantities than where trees are sparse. The greater fuel accumulation in turn supports a hotter fire that thins the stand in proportion to the fire's heat. As in older reproduction stands, it is chiefly the smaller trees that are removed by fire —almost no trees in the largest size classes were killed on the Horse Mesa plots.

## EARLY GROWTH OF THE PRESENT MATURE STAND

One of the more significant problems to be considered in evaluating changes in forest conditions over the past century is the early growth of those trees that comprise the present mature stand. The growth pattern of these trees was presumably governed in their sapling stage by the same factors that control the growth of young stands today.

Growth of 104 trees more than 100 yrs old on the Maverick plots was analyzed from increment cores. From each core, 2 tree diameters were derived, one at about 25 yrs of age and the other just 20 yrs later. These diameters were used to compute the stem area growth during a 20-yr period in the early life of each tree. A 20-yr period was chosen to minimize the effects of brief chance variations in weather. It has already been demonstrated that in the age range from 20 to 55 yrs, stem area growth in a single tree remains relatively constant from one decade to the next. It is therefore legitimate to divide the calculated 20-yr growth by 2 to estimate the mean 10-yr growth during the early life of the present mature stand.

This estimated 10-yr early growth of the 104 mature trees was compared with the graph of growth of the largest trees in the present day sapling stands (Fig. 16). Two assumptions were involved here: that the trees now comprising the mature overstory were the largest, dominant trees in the stand when they were saplings; and that the same factors that now govern the growth of dominant trees in sapling stands were operative a century and more ago. From the relation between tree growth and stand density given by Figure 16, an estimate was made of the probable stand density under which each of the mature trees must have grown when it was about 35 yrs of age. The estimated past stand densities of the present mature stand were compiled in a histogram (Fig. 23). More than 23% of the trees examined exhibited an early growth pattern comparable to that now shown by trees growing in stands with less than 1000 stems per A. More than half of the present mature stand apparently grew up in stands with fewer than 3000 trees per A at 35 yrs of age.

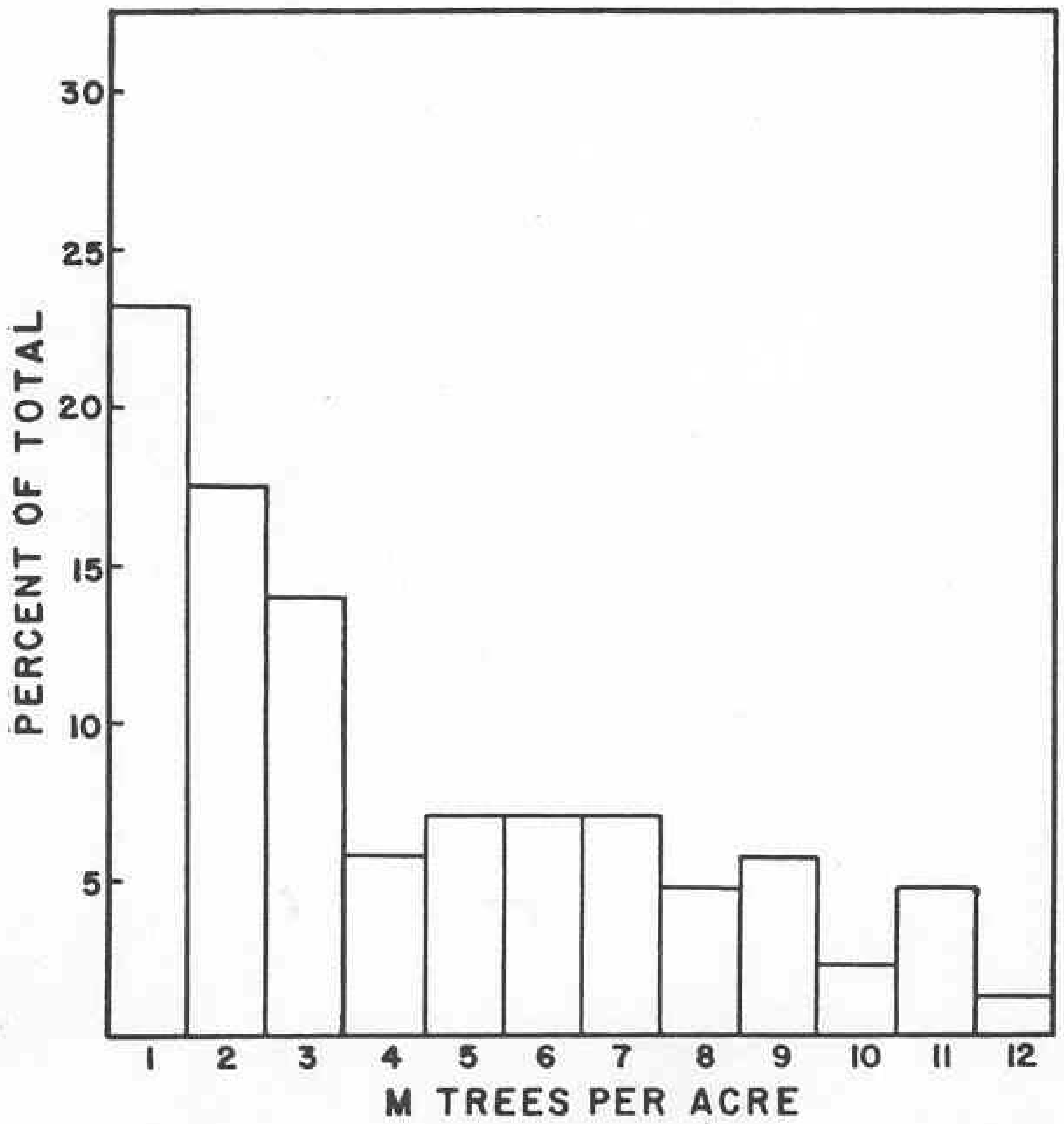


FIG. 23. The early growth of 104 trees from the mature stand at Maverick was used to estimate the stocking density under which these trees may have grown in their early years.

One of several questionable assumptions in this analysis is the conclusion that all of the present mature stand developed from trees that were large dominants in the sapling stands of their youth. Some of the present overstory trees have, on the contrary, rather obviously been more or less suppressed all their lives. It is not uncommon to find 6- or 8-in. trees that are 150 yrs or more old. Several such were included in the Maverick growth analysis. Besides the trees used in the construction of Fig. 23, there were 18 additional trees whose early growth was so small as to indicate that they grew up under a stocking rate far in excess of 15,000 stems per A. This is surely improbable. It is more likely that these 18 trees were small intermediate or codominant trees in their sapling days.

All that Figure 23 suggests with any degree of certainty is that the early growth of a large proportion of the trees that make up the present mature stand was greater than the comparable growth of most saplings today. The implication is very strong that most of the Maverick overstory began its life under conditions of stocking considerably less dense than those found in the area today.

## Sapling Stands at Maverick and Malay Gap

Because of the marked difference in site quality and stand character between Maverick and Malay Gap, it is not legitimate to compare directly the growth of trees on the two areas. Fewer stands were sampled for complete growth data at Malay Gap than at Maverick.

The average growth of the largest trees in the Malay Gap sapling stands is much less than that of trees in stands of comparable density at Maverick. Measured stem area growth of dominants at Malay Gap is only about two-thirds that predicted from equation (4) and Figure 16. The lower site quality at Malay Gap accounts in part for this difference. More important, though, is the fact that the Maverick growth equation defines growth in sapling stands of wholly different character than those at Malay Gap.

The Maverick equation related growth to stand density in stands whose structure has been determined almost wholly by biological factors of intraspecific competition. These stands have a high proportion of small trees, whereas the fire-thinned stands at Malay Gap tend to have fewer but larger trees. It has been shown (Cooper, in press) that instantaneous growth rates in ponderosa pine stands are more closely related to summed tree diameters per acre than to basal area or to number of trees per acre. This is logical when it is considered that tree diameter is almost directly proportional to the surface area of the cambium.

Because the Malay Gap stands contain fewer very small trees than those of comparable age at Maverick, the summed tree diameters in stands of a given density are greater at Malay Gap than at Maverick. This means that the influence on stand growth of a given number of trees per acre is greater at Malay Gap than in the Maverick stands. Therefore, even aside from site quality, it is to be expected that individual tree growth would be less in stands of a specified density at Malay Gap than at Maverick.

It is likewise not legitimate to compare the total periodic basal area growth per acre of the two sets of stands. The basal area of the Malay Gap stands was sharply but temporarily reduced during the 1948-1957 decade by the fire of 1943. This fact, combined with the known site differences, makes a direct comparison of basal area growth meaningless.

Definite conclusions can, however, be drawn about the diameter distributions and the comparative stand densities in the two areas. The differences in diameter distributions in sapling stands at Maverick and Malay Gap have already been discussed in some detail. Differential removal of smaller stems by fire is plainly the mechanism which produced the Malay Gap diameter distributions. The 1909 stands at Maverick were all exposed to at least one fire early in their lifetime. This fire removed some of the surplus smaller stems, and initiated a change toward a diameter distribution of the type found at Malay Gap. These stands were fully protected after the age of 15, though, while the comparable stands at Malay Gap were being burned twice more. The sapling stands whose distributions are most strongly skewed toward the small trees are those young ones never exposed to fire. Those most strongly skewed toward the large end of the distribution are the Malay Gap and the much older Cooley Mountain stands, all often subjected to surface fires. Intermediate in diameter distribution are the once-burned 1909 stands at Maverick.

Diameter distributions at earlier ten-year intervals were derived for several stands from measurements of stump sections and increment cores. The shape of the logarithmic basal area histogram changes very little in the interval from about 20 to 50 yrs total age. Variations in shape of the histograms in Figures 8 and 9 seem to be attributable chiefly to environmental factors rather than to normal changes in diameter distribution accompanying stand maturity.

Another striking difference between Maverick and Malay Gap is in the average density of reproduction stands. The comparative figures of Table 6 are probably representative of the difference in the two areas. Nowhere at Malay Gap are there impenetrable pine thickets of the type so common elsewhere (Fig. 24). A reasonable effort was made to include in the sampling program the densest stands observed at Malay Gap. The most densely stocked 1/100 A that met the other sampling requirements of homogeneity and stand uniformity had the equivalent of 4960 trees per A.

FIG. 24. Closeup of a typical dense thicket at Bog Creek. Cap in foreground gives scale. There is no lack of light on the forest floor even in the densest pine stands.

The lower stand density and the greater relative number of trees in the larger size classes means that the mean growth per tree is greater in the fire-thinned stands at Malay Gap than in stands of comparable age in other areas. The stands at Malay Gap appear more healthy, more open, and are composed of fewer but larger trees than at Maverick (Fig. 25).

It is clearly apparent that reproduction stands are smaller in extent at Malay Gap than elsewhere in the Arizona pine region. Yet, a survey showed that one-fourth of the ground area there was occupied by stands less than 40 yrs of age (Fig. 6). This is surely a normal proportion in a forest of long-lived trees.

## THE ORIGIN OF PATTERN AND STRUCTURE

### AGE AND DIAMETER STRUCTURE

An important characteristic of the old-growth forests of the White Mountains is their unbalanced age and size class distributions. There is an over-abundance of young trees less than 6 in. d.b.h., and many large mature and overmature pines. The intermediate age and size classes are obviously deficient.

FIG. 25. Pine stand at Malay Gap, partially thinned by recurrent fires. This stand originated in 1914.

The missing classes coincide in general with the period of first settlement of the Southwest, and it has been suggested that the early pioneers were responsible for the present lack of intermediate aged stands. It has been reported that the early settlers were particularly careless with fire, or perhaps set fire to the woods deliberately to improve forage conditions. An abnormal increase in the incidence of man-caused fires in the last half of the 19th century is sometimes assigned as the cause of the relative lack of small sawlog trees in the ponderosa pine forest.

The fact that the same unbalanced age distribution occurs in the largely undisturbed forest at Malay Gap argues against this hypothesis. Furthermore, there is little evidence that the early pioneers were particularly free in their use of fire in the woods. Joe Pearce, a long-time resident of Eagar, Arizona, who was employed as the first ranger on the Black Mesa Forest Reserve at the time of its establishment in 1898, reported (personal interview, 1957) that his principle duty in those days was firefighting. He had little trouble enlisting the aid of cattlemen in fighting fire on their own range, for they were constantly apprehensive about the loss of forage. In contrast to the situation in California, there apparently was little organized burning of the woods by white settlers at any time in the last century.

The primary cause for the lack of intermediate aged trees appears to be the infrequent occurrence of the peculiar sequence of weather conditions necessary for establishment of reproduction. There is a large class throughout the White Mountains that apparently dates from about 1839. Most of these 120-yr-old trees are now from 16 to 24 in. d.b.h. There are definite age classes that originated about 1875, about 1890, and possibly in other years; but on the whole there was little regeneration between 1839 and 1909. Many of the present small pole stands started in 1909, and were followed by the extensive 1919 class.

Several older classes can be clearly distinguished. Many trees became established in 1820 and others about 1795. A surprising number of the very large veterans in the old-growth forest can be dated about 1685.

The importance of the 1919 age class has been stressed repeatedly, and perhaps overemphasized, by many foresters. It is almost wholly lacking in the Maverick area, however. Fire scars on trees in the 1909 pole stands show that the area was burned early in the growing season of 1924, when the 1919 pines were 5 yrs old. If any substantial number of seedlings became established in 1919, they must have been killed by the 1924 fire. It is possible that there was a complete local failure of reproduction at Maverick in 1919. This hypothesis is made plausible by the apparent scarcity of 1919 trees over many square miles, and their relative rarity at Malay Gap. A number of stands that appeared to date from 1919 were sampled, but all turned out to be somewhat younger. Dense pine thickets originating in 1923 and 1928 are as conspicuous in the Maverick region as are the 1919 thickets elsewhere. For the last 25 yrs or so there has been virtually complete failure of pine regeneration throughout the White Mountains.

The age and diameter structure of the forest as a whole is governed by the periodicity of reproduction. A particularly favorable combination of weather conditions has permitted stand regeneration only in occasional years. These waves of reproduction have come at irregular and unpredictable intervals, and have resulted in an irregular and unbalanced forest structure.

## PATTERN

The patchwork pattern of the ponderosa pine forest is the expression of a cyclical process of community development, governed by fire and by the intolerant nature of the species. The basic outlines of this process have been presented by Weaver (1943). Watt (1947) has analyzed the theoretical implications of cyclical development in the plant community. It remains to bring these concepts together into a unified hypothesis on the origin and development of pattern in the southwestern pine forest.

The intolerance of ponderosa pine to shade is responsible for the formation of the even-aged groups of which the forest is composed. Even-aged forests are typical of intolerant species in general, for the young trees grow best when not subjected to shade from the mature canopy. The relatively small size of the even-aged groups in the southwestern forest is due to the small size of the openings in which the groups can become established.

As the stand matures, the identity of the groups is maintained by fire. In an opening, a stand of young trees is partially protected by the lack of fuel on the forest floor. In contrast, the ground beneath a group of mature trees is generally covered by a layer of inflammable material. Seedlings that germinate beneath the overstory are rapidly eliminated by the first fire that passes through the stand.

Fire is thus the force that here counteracts the inevitable tendency of plants to take on a random distribution. Since the seeds of ponderosa pine are widely and more or less uniformly distributed throughout the entire forest, the stand should in time take on a purely random pattern, the pattern of a theoretical all-aged forest with trees of every age occurring in every portion of the stand. Some external influence must be present to overcome the natural tendency for pattern formations to break down and for the vegetation to be distributed randomly. Natural fires impress upon the forest the grouped pattern so characteristic of ponderosa pine, and act to maintain that pattern through time.

Watt (1947) has suggested that most plant communities exhibit a cycle of change divisible into two parts: an upgrade, when the net quantity of plant material is increasing; and a downgrade, characterized by dispersion of material and the breakup of the community. The upgrade portion of the cycle starts slowly, accelerates, and then slows down as the community reaches maturity; the downgrade portion of the curve is precipitous.

A reconstruction of the history of one small area of about ¼ A at Maverick illustrates the cyclical pattern of development and breakdown through which the pine forest has passed. This particular quarter-acre is occupied by a dense stand of young pines that originated in 1928. Towering above them are two old veterans, one 34 in. and the other 35 in. d.b.h. Two standing snags, 4 fallen logs, and a burned stump testify that the two big trees are the last survivors of a disintegrating group. Close by in all directions are thrifty pole stands dating from 1909.

The group of large pines, which began to grow about 1715, was apparently still intact in 1909, and then consisted of about 10 mature trees. When the 1909 stands established themselves, seedlings germinated beneath the mature canopy, but grew poorly because of root competition. The first fire that came through the area—in 1924 if not before—killed them all because of their small size and because of the quantity of surface fuel laid down by the overstory pines. Adjacent young stands in openings survived, to produce the thrifty pole stands visible today.

Meantime, the mature stand was starting to break up. One of the old trees must have been dead by 1924, as shown by the burned stump. After maintaining its integrity for more than 200 yrs, the group apparently disintegrated in 20 yrs or less. Interconnection of the root systems by root grafts may have had something to do with the rapid deterioration of the stand once disease or old age got a foothold. With all but 2 or 3 of the former dominant group gone, conditions by 1928 were suitable for reestablishment and survival of a new young stand. The 1924 fire removed most of the surface litter and exposed a good seedbed. There was no longer a heavy needle fall from the mature overstory, nor did the feeble survivors offer intense root competition to the developing young stand. Thus a new cycle was initiated, to repeat itself as before. Under natural conditions, the new young stand will throughout its life maintain its integrity as a homogeneous even-aged group. Root competition combined with selective removal of small stems by fire will ensure that trees of younger ages cannot successfully become established within the even-aged group.

## GROUND COVER VEGETATION

The composition and quantity of the herbaceous ground cover in Southwestern ponderosa pine forests is the result of the interaction of at least three factors: grazing, fire, and the density of the forest canopy. The relationship of fire to ground cover vegetation has been intensively studied in the pine regions of southeastern United States, where prescribed burning is widely employed to control undesirable hardwoods. The situation in the Southwest is somewhat different, for here there is no evident successional trend leading to replacement of pine by other species.

No detailed studies have been made of the effects of fire on subordinate vegetation in the Southwest. Weaver (1951b) concluded that properly conducted prescribed burning does not seriously damage perennial bunchgrass cover under ponderosa pine. In fact, it appears beneficial through partial opening of the reproduction stand and removal of dense needle mats. He considered the same to be true where periodic surface fires have continued.

The herbaceous cover at Malay Gap was the only ground cover vegetation that was analyzed in detail in the present study. The Malay Gap area is especially interesting in that livestock have been virtually excluded, and the ground cover approximates to some degree that of pre-white man days. The district is an important wintering ground for the elk that move down from the high country to the east, so it can by no means be considered entirely ungrazed.

The ground cover at Malay Gap is composed almost wholly of a dense stand of screwleaf muhly (*Muhlenbergia virescens*). A few other grasses and forbs are present, but in most places more than 90% of the volume of herbaceous cover consists of the one species of *Muhlenbergia*. Other species present are *Blepharoneuron tricolepis, Sitanion hystrix, Panicum bulbosum, Stipa pringlei, Poa fendleri,* and *Koeleria cristata*. On dry exposed slopes, *Muhlenbergia rigens, M. longiligula,* and *Ceanothus fendleri* become more abundant. It is clearly noticeable that forbs of all kinds are much scarcer at Malay Gap than on most comparable sites on the Fort Apache Reservation and adjacent national forests. This difference is almost surely due to differences in grazing history.

The grass cover at Malay Gap is as dense as is to be found anywhere in the southwestern pine zone. Grass production was estimated by harvesting all of the current year's crop within a rectangular wire frame 9.6 sq ft in area. The weight in grams of the grass from one such plot, multiplied by 10, estimates grass production in lbs per A. The estimated weight of the current year's forage production in openings at Malay Gap was 1620 lbs per A. The standard error of the mean of this estimate is 108.5 lbs. While plant species other than screwleaf muhly were encountered on most of the plots, they occurred in such small quantities that it was impractical to segregate them.

The volume of the herbaceous ground cover is much greater in the open than under the forest canopy (Fig. 26). Ground vegetation was harvested from plots under several degrees of tree cover. Percentage of crown cover was estimated at each sampling point by means of the spherical densiometer described by Lemmon (1956). Seven such points were sampled. Based on 20 separate 9.6 sq ft plots from these 7 points,

$$V = 1600 - 21\ C \qquad (9)$$

where V is herbaceous cover in pounds per acre and C is percentage of crown cover, expressed as a whole number. The standard deviation of the regression coefficient is 2.5. This equation states that forage production declines about 21 lbs per A for each 1% increase in crown cover. If projected far enough, the equation indicates no herbaceous vegetation at crown densities above about 75%. This is essentially correct, for there is little such vegetation beneath very dense pine stands.

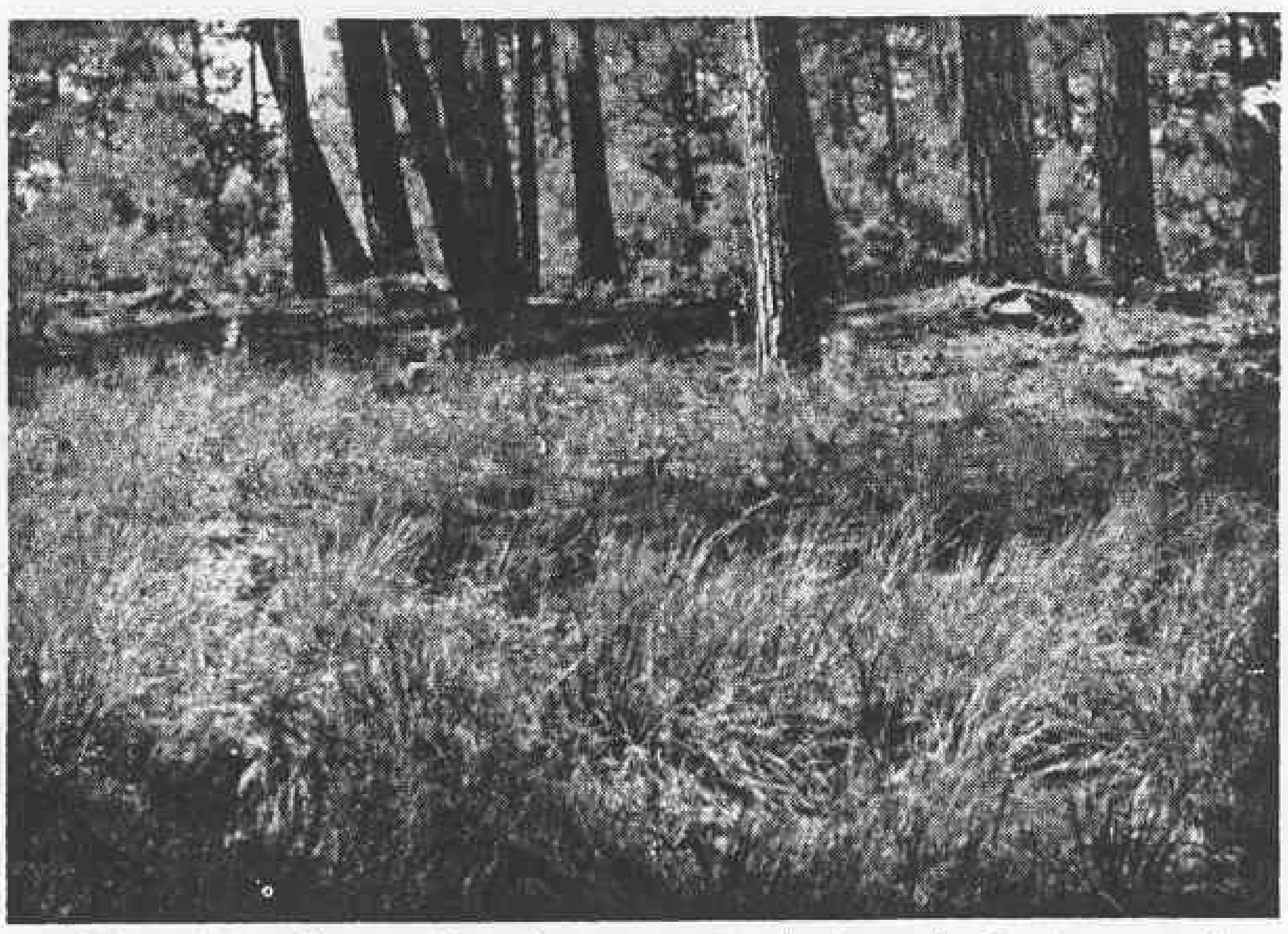

FIG. 26. Grass development in intervals between pine groups at Malay Gap. Note the virtual absence of grass and the accumulation of pine needles beneath the mature group in the background.

No detailed analysis of fire effects on grass cover was made. Observations on the B.S. Gap fire indicate that about 10% to 15% of the grass plants were dead a year following the fire. This fire burned at the very end of the growing season, when grasses were nearly dormant, although screwleaf muhly remains partially green all winter. Dead grass plants were clearly evident in the adjacent unburned area as well, so that many of the dead clumps observed on the B.S. Gap fire might have been due to natural mortality. Few grass seedlings were present. While grass growth was vigorous on the burn, it was noticeably less so than on the adjacent unburned area.

### EFFECTS OF FIRE ON SOILS

The effects of fire on soils and on watershed condition have long been a matter of concern. The Annual Report of the Superintendent of the Fort Apache Agency discussed a series of severe fires that took place in the summer of 1904. "These fires were high in the mountains and far from the Agency or Indian homes, and in places almost inaccessible. There was not much damage to the large timber, but the younger growth was almost destroyed. The greatest damage, however, was the burning of the great beds of leaves that conserve or hold the water on the mountain sides. The effect was seen in the great floods that came last winter from the continued rains and the deep snow." (Crouse 1905). Yet, as has already been noted, fires were frequent in the White Mountains for many years before 1904, and accelerated erosion was not severe over most of the area at the turn of the century.

Detailed studies of soil conditions following fire in the White Mountains have been reported elsewhere (Cooper, in press). Under most conditions, a protective layer of duff remained on the forest floor following burning. Soil movement was measurably increased on steep slopes after fire, but the slopes rapidly stabilized and little of the eroded material actually reached stream channels. Soil erosion following light to moderate fires cannot be considered serious on the basalt soils of the White Mountains.

## DISCUSSION AND CONCLUSIONS

### CHANGES SINCE WHITE SETTLEMENT

The coming of the white man to the Southwest brought many new factors to disturb the ecological balance of the region. Most important were the attempted exclusion of fire from forests and ranges, and introduction of domestic livestock. Both have contributed to changes in the Southwestern pine forests during the last three-quarters of a century, but of the two, protection of the forests from fire has had the greatest effect.

Natural surface fires were the agent which normally thinned young stands of pine reproduction—sometimes too much, sometimes not enough, but on the whole in such a manner as to insure continuous growth of the forest. The pattern of the forest, a pattern of an all-aged stand made up of even-aged groups, was largely maintained by fire.

Fires were started by lightning and by Indians. It is impossible to determine the proportion caused by each. Northern Arizona is an area of extremely high lightning incidence; anthropological studies attest to the role of historic Indians in setting fires. It is likely that prehistoric Indians, who have occupied the region for at least 10,000 yrs, were equally free in their use of fire. It is probable that genetic and evolutionary processes, operating over that length of time, would have brought the ponderosa pine forest into balance with the existing fire regime. The arrival of the Indians may have intensified the extent of fire in the forest, but lightning fires were prevalent long before.

When the white man brought his cattle and his fire-fighting crews to the Southwest, the forest began to change. Grazing altered both the composition and the quantity of ground cover vegetation. Removal of herbaceous competition and exposure of mineral soil by livestock helped prepare the ground for dense thickets of pine reproduction. Abundant reproduction would have become established in any case, however, for its principal cause was an unusually favorable series of weather conditions.

With few fires to thin dense stands of young pine, they soon grew into almost impenetrable sapling thickets. Man's attempted exclusion of fire without the substitution of some other agent to thin sapling stands and to remove excess fuel has created a condition of near stagnation and of fire hazard that presages no good for the forests of the Southwest.

### IMPLICATIONS FOR MANAGEMENT

This study was planned as an investigation of the ecological effects of natural fires in the ponderosa pine forests of Arizona. It was not intended as an evaluation of the controlled burning program being carried out on the Fort Apache Indian Reservation, nor as a study in applied forest management. Nevertheless, no one interested in forest management can avoid drawing some conclusions after intensive effort on a problem of this kind.

Early students suggested that repeated fires were permitting the ponderosa pine forests to produce no more than 40% of their potential growth. It is clear that growth of the primeval pine forests did not reach the maximum potential productivity of the site. Natural fires thinned some sapling stands too severely, and killed an occasional large tree in its prime. Growth surely exceeded 40% of the potential, though; it was perhaps nearer 80%. Under present policies of complete exclusion of fire from most of the forests of the Southwest, growth of young stands has actually declined.

Whether the trend toward excessively dense pine thickets, with their accompanying problems of stagnation, can be reversed and the forest returned to anything like its original condition by the use of prescribed fire is questionable. Forty years of fire protection have perhaps allowed the situation to get beyond control. The pine thickets have grown up to a point that a planned burn is apt either to destroy the whole stand or to do little in the way of needed thinning. It may be that only in newly established stands originating after timber harvest can the silvicultural possibilities of planned fire be fully realized.

Three conclusions seem plain from this study. The first is that some practical and economic means must be found for thinning young pine stands and for reducing the amount of hazardous fuels. At the dense stocking rates characteristic of most of the pine thickets in northern Arizona, virtual stagnation is setting in. The fire hazard is likewise building up to dangerous levels. The projected pulp industry in Arizona, often held out as a panacea for all the ills of forest management, will do little to remedy the situation. The stands in most urgent need of thinning are those well below pulpwood size. If fire is not to be the tool to do this needed job, some other efficient and inexpensive means must be found to thin the stands and remove surplus fuel.

Secondly, if fire is to be used as a management tool in the ponderosa pine forest, some modifications will have to be made in the present system of marking trees for harvest. The improvement selection method used in the Southwest removes high-risk trees and larger dominants where ever found, favoring the growth of smaller clean-boled trees. If applied over several cutting cycles, this system will eventually convert the forest to a true all-aged condition, with trees of every age on every small unit of the stand. If the natural even-aged group pattern of the forest is thus broken up, it will be impossible to employ fire as a management tool. Seedlings under the cover of a mature tree canopy cannot withstand a fire, natural or planned. Only if the normal group pattern is maintained, permitting seedlings to grow in openings, can reproduction be secured. Some version of the group selection system, now being tested in Idaho ponderosa pine stands (Curtis & Wilson 1958), will be necessary to assure regeneration if fire is to be used as a management tool.

Finally, it must be recognized that small trees in and beneath an even-aged stand are not only not desirable, but are often a positive hindrance to growth. In most cases it is impractical in the Southwest to attempt to establish advance reproduction many years before harvest of the mature stand. The statement of Gaines *et al.* (1958) that in the experimental burns on the Fort Apache Reservation, "Few seedlings less than 3 or 4 feet tall survived on either burned area," is technically accurate but highly misleading. Almost without exception these 3 and 4 ft "seedlings" were no less than 25 yrs old at the time of the fire. Removal of these stunted trees represents a gain to forest management, and not a loss as they imply.

The ponderosa pine forest found by the first white men originated under the influence of fire, and was fully attuned to fire as a part of its natural environment. Forty years of fire exclusion has induced profound and detrimental changes in the growth and structure of the managed forests of the Southwest.

## SUMMARY

The late settlement of the region makes northern Arizona particularly suitable for a study of vegetation change resulting from man's use of the land. Changes in the ponderosa pine forests of southwestern United States have been studied through analysis of the historical evidence and of the structure of the present forest stand.

Reports of early visitors indicate that the forest was originally more open than it is today. Dense thickets of young ponderosa pine have covered much of the region in the last half century. Accompanying the increase in young pines has been a decrease in grass cover and a shift in the botanical composition of the herbaceous vegetation. Accelerated erosion has removed the surface soil layers and induced formation of gullies in some places.

Long term climatic changes do not appear to be a major factor contributing to these changes, nor do the effects of wild animals. Some of the change in herbaceous vegetation is the result of excessive use by domestic livestock, but much is directly due to the increasing density of the pine overstory. Livestock have initiated some of the increase in pine reproduction by reducing grass competition and by exposing a mineral seedbed that makes seedling establishment easier.

The most important change brought about by the white man has been the virtual exclusion of fire from the forests of the Southwest. Under natural conditions, light surface fires, set by lightning or by Indians, burned through all parts of the pine forest at regular intervals of 3 to 10 yrs. These fires acted as natural thinning agents and reduced surplus fuel. The reduction of inflammable grass by grazing animals, and an intensive fire prevention program have largely eliminated fire from the woods. The major cause of the present excess of pine reproduction is exclusion of fire.

Stand structure was studied in two areas typical of the ponderosa pine forests in most of the Southwest, and at the primitive area at Malay Gap, where livestock have been excluded and natural fires have continued. In all the old-growth stands examined, there are fewer trees in the intermediate size classes, from 8 to 20 in. d.b.h., than would be expected from theoretical relations between size classes. There are fewer trees in the age classes from 80 to 120 yrs than expected. In young even-aged stands, diameter distributions are skewed toward the smaller trees in stands never exposed to fire. In stands frequently burned during their development, diameter distributions approach a log-normal form, and conform to theoretical distributions that have been fitted to even-aged stands elsewhere.

Mean growth per tree in even-aged reproduction stands is a linear function of available space per tree. From age 20 to 55 yrs, mean growth per tree in any one stand remains relatively constant from one decade to the next. Apparent stagnation begins as stand density exceeds about 6000 stems per A. 150 to 450 trees per A yield maximum growth per tree. Total basal area growth per acre increases with stand density, then decreases as stocking exceeds 4000 trees per A.

Since competition is mostly for water, not light, the normal suppression pattern characteristic of humid forests does not occur in southwestern ponderosa pine. Small trees continue to grow at a constant slow rate, and suppressed and intermediate trees in the aggregate play a greater role than is usually attributed to them. Natural mortality is low in stands unaffected by fire.

Growth of potential crop trees is a linear function of the logarithm of stand density. Stem area growth of an individual tree is directly proportional to the weight of the current year's needles. Height of dominant saplings is related to stocking and age of stands as well as to site index.

The pattern of mature stands and of reproduction stands was analyzed with a grid of contiguous quadrats. Trees are aggregated into even-aged clumps averaging .16 to .32 A in size. The pattern of reproduction in unburned stands is less distinct than that of the mature stand, or of the reproduction in frequently burned stands at Malay Gap.

The stand at Malay Gap is much more open than that in the unburned area at Maverick, with more grass in the intervals between the trees. The site is not as good at Malay Gap as at Maverick, but the difference in stand conditions is primarily due to the frequent fires which have continued at Malay Gap, and to differences in grazing history. Small saplings are rare beneath the mature canopy at Malay Gap. They have been removed by surface fires supported by fuel dropped by the mature stand. Reproduction at Malay Gap is successful only in openings where there is little fuel. There are many more trees per acre in reproduction stands at Maverick than at Malay Gap. Stocking at Malay Gap, however, is fully adequate to assure a future timber crop.

The effects of a recent natural fire were studied at Malay Gap. Only 18% of the trees less than 1 in. d.b.h. survived the fire. Survival in the 4- to 6-in. class was 84%, and no trees over 8 in. d.b.h. were killed. Natural fires thin sapling stands in three ways: by direct heat damage to the cambium of individual trees, by general raising of the crown level, and by creation of openings around burning logs and stumps. In very young stands, there is rarely enough fuel to carry a fire until the trees are 6 or 8 yrs old. The density of the sapling stand in part regulates the quantity of dry needles and the intensity of the resulting surface fire. Fire thinning of sapling stands is a sort of self-regulating feedback mechanism in which the degree of thinning is governed by stand density.

Analysis of early growth of trees comprising the present mature stand at Maverick showed that their growth in the sapling stage was greater than that of most trees of comparable age in present young stands. The implication is that the older trees began their life in relatively open sapling stands.

The unbalanced size and age class distribution in old-growth stands is due chiefly to the rarity of the peculiar set of weather conditions needed for stand establishment. Trees of only a few distinct age classes are present, and failure of reproduction over a long period in the last century accounts for the relative lack of 8- to 20-in. trees.

The clumped pattern of ponderosa pine is the result of a cyclical pattern of community development, governed by fire and by the intolerant nature of the species. Fire is the force that counteracts the tendency of trees to take on a random distribution.

The composition and quantity of the herbaceous ground cover is governed by grazing, fire, and the density of the forest canopy. Little serious erosion can be noted following light surface fires.

It is doubtful if, after 40 yrs of protection, use of prescribed fire can now reverse the trend toward excessively dense pine thickets. Silvicultural possibilities of planned fire can probably only be realized in young stands originating after timber harvest. Some practical and economic means must be found for thinning young pine stands and for reducing the amount of hazardous fuel. If fire is to be this means, modifications will have to be made in the present method of marking trees for harvest, which is rapidly converting the even-aged groups into a true all-aged forest. In general, small trees in and beneath an even-aged group are not only not desirable, but are often a hindrance in managed forests.

The ponderosa pine forests of the Southwest evolved under the influence of natural fires. Man's attempted exclusion of fire and introduction of livestock has induced marked changes in the vegetation of the region.

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ITEM B:

4FRI Old and Large Tree Retention Strategy

September 13, 2011

# Old Growth Protection
# &
# Large Tree Retention
# Strategy

# Contents

## I. Old Growth Protection & Large Tree Retention Strategy (OGP&LTRS) Overview

The goals of the Four Forests Restoration Initiative (4FRI) are to restore healthy, diverse stands, supporting abundant populations of native plants and animals; to protect communities in forested landscapes from destructive wildland fire; and to support sustainable forest industries that strengthen local economies while conserving natural resources and aesthetic values. In short, we seek to re-establish largely self-regulating forested landscapes including their associated fire regimes through a process of ecological restoration that benefits communities, economies, ecosystems and biodiversity.

Ecological restoration will require thinning post-settlement ponderosa pine trees[1] in unnaturally dense stands. While there is broad agreement for reducing small diameter tree densities, where and how this should be done has often been the subject of social and scientific debate. The purpose of this document is to affirm recommendations of the 4FRI Stakeholder Group relating to the retention of large post-settlement and old growth trees—recommendations that are critical to moving beyond those debates—and to provide specific, science-based recommendations for incorporation into 4FRI restoration plans and projects.

**Retention of Old Growth and Large Post-settlement Trees**

"The Path Forward"—a foundational document of the 4FRI—calls for blanket old growth protection, regardless of tree size. It states that, "No old-growth trees (pre-dating Euro-American settlement) shall be cut." The document also includes broad recommendations for retaining large post-settlement trees with some carefully specified exceptions.

In southwestern ponderosa pine forests, old-growth trees are important to ecosystem structure and function. They increase genetic diversity on the landscape; old trees have greater genetic diversity than even-aged groups of young trees (Kolanoski 2002) and, thus, may have a better chance of adapting to changing climatic and environmental conditions, an ability they can pass on to their progeny. In addition, when not surrounded by large amounts of fuel, the thick bark of old-growth trees makes them largely resistant to low-intensity surface fire (Agee 1998). Old-growth trees also increase forest structural diversity, which, in turn, provides more wildlife habitat. For example, large trees provide additional structure for bats, which roost under slabs of bark; nest trees for northern goshawks and Mexican spotted owls; continuous canopy for tassel-eared squirrels; and foraging habitat for bark-gleaning birds (Bull and Hohmann 1994, Humes et al. 1999, Dodd et al. 2003). In addition, old trees often become long-lasting snags when they die, which benefits many species of cavity-nesting birds and mammals (Chambers and Mast

[1] Large and old growth tree recommendations offered in this document refer specifically to ponderosa pine trees.

2005). Old, large trees also serve as long-term carbon stores (Harmon et al. 1990) and preserve a record of the past that can inform future research about insect outbreak, fire history, and climate change (Fulé et al. 1997, Soulé and Knapp 2006). Finally, old-growth trees enhance the aesthetics of forests (Brown and Daniel 1984) and, thus, increase public support for restoration projects. Old-growth trees are present on the landscape at similar or lower densities compared to presettlement times (Mast et al. 1999, Moore et al. 2004), depending on how many trees have been removed postsettlement by forest management practices (e.g., clearcut, thinning, seed tree, etc.). The three main threats to old-growth trees are high-severity wildfire, competition from mid- or under-story trees, and drought and subsequent bark beetle attacks (Kolb et al. 2007). Restoration treatments (thinning and prescribed burning) around old-growth trees can cause some mortality. However, this threat can be reduced through careful management (Hood 2010). In addition, restoration treatment should result in a reduced threat of wildfire, a release from competition, and increased tree growth (Fajardo et al. 2007, Fulé et al. 2007).

The Path Forward also calls for retaining large post-settlement trees (defined by the socio-political process as those greater than 16 inches diameter-at-breast height [dbh]) throughout the 4FRI landscape, except: (1) as necessary to meet community protection and public safety goals within the Community Protection Management Areas identified in the Analysis of Small Diameter Wood Supply in Northern Arizona and where stakeholder agreement identifies priority areas within approved CWPPs; and (2) when best available science and stakeholder agreement (as defined in the 4FRI Charter) identify sites where ecological restoration and biodiversity objectives cannot otherwise be met – specifically wet meadows, seeps, springs, riparian areas, encroached grasslands, aspen groves or oak stands, within-stand openings, and heavily stocked stands with high basal area generated by a preponderance of large, young trees.

We recognize that there are multiple causes of ecological degradation that may not be affected by mechanical thinning and different types of burning. The exceptions articulated in the following section are intended to be part of a more comprehensive and concurrent approach to treating causes (rather than just symptoms) of ecological decline. To that end, we are asking the Forests to work collaboratively on a comprehensive restoration assessment that identifies possible management actions to stem/reverse ecological decline. We believe this restoration assessment should focus on a wider range of forest resources than just timber and fire; such as hydrology, range, recreation, and wildlife. We ask the four National Forests to initiate this assessment with the 4FRI Stakeholders, upon release of the Draft EIS for the first project area.

The intention of the exception process is to increase landscape heterogeneity and conserve biodiversity. Thus we do not support implementing any exceptions where removing the trees would conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat. We also recognize there may be additional areas and/or circumstances where large trees need to be removed to achieve restoration. These circumstances should be identified through a site-specific, agreement-based, collaborative process as described in the 4FRI Charter.

## II. OGP&LTRS Rationale: The Historical Debate Regarding Diameter Caps in the Southwest and the 4FRI's Large Tree Retention Policy

**Introduction**

Diameter caps for tree cutting have been used in forest management efforts across the West. They have been and continue to be the subject of much debate. In this section of the Large Tree Retention Strategy document, two different perspectives on diameter caps are presented. Recognizing that the 4FRI Large Tree Retention and Old Growth Protection Strategy is not meant to serve as a strict diameter cap, these perspectives are offered here to illuminate elements of the historical debate that have led to the 4FRI's formulation of the existing Large Tree Retention and Old Growth Protection Strategy.

**Arguments in Favor of Diameter Caps**

There is a generally recognized need to retain larger trees and protect old growth in southwestern ponderosa pine forest restoration. Some proponents of large tree retention have suggested that a 16" diameter cap is both ecologically and socio-politically warranted given the scarcity of mature and old growth forest cover in the region; the need to quickly re-establish lost mature and old forest structure; the necessity of retaining trees larger than 16" dbh to recruit new trees into regionally-underrepresented VSS 5, 6 and "old growth" structural stages; and the regional rarity of trees larger than 16" (approximately 96% of ponderosa pine trees in northern Arizona and New Mexico are smaller than 16-inch dbh).

Such proponents have proposed diameter caps as a means to (1) prevent large-tree logging for production-oriented, uneven-aged silvicultural goals, (2) discourage large-tree logging to pay for small-tree thinning or other activities, (3) favor small-diameter-specific industries over large-tree-dependent ones, (4) avoid population-level effects to imperiled species and wildlife that are associated with larger live and dead trees and denser canopy, (5) mitigate unforeseen large tree mortality during and following restoration treatments, (6) mitigate unknown rates of future large tree mortality resulting from re-establishing natural fire regimes and future climates, (7) mitigate under-estimates of historical tree densities owing to evidence undercounting and loss to fire, logging and decay, (8) accommodate differing reference scales, choices of reference attributes, restoration objectives and desired degrees of precision or rates of change, (9) mitigate uncertainty about future national forest policy, timber and wildlife habitat management, and (10) facilitate a restoration approach that reduces immediate crown fire threat while incrementally moving the forest toward its natural range of variability through a combination of thinning and natural fire.

Diameter limits and exception-thresholds for tree cutting are a common strategy for achieving ecological objectives in western forest landscapes. In their recommendations to Congress and the President, the Eastside Forests Scientific Society Panel proposed a 20" diameter limit for trees younger than 150 years old to protect late-successional and old-growth dry forests of eastern Oregon and Washington. They cited the ecological importance and scarcity of large and old trees and the need to retain them to replenish regionally-depleted supplies of large and old trees, snags, logs and associated wildlife habitat. Those recommendations formed the basis for interim management direction amending nine national forest plans and establishing a 21" diameter limit in dry forests which in turn carried forward into an exception-threshold of 21" diameter in legislation proposed to restore dry forests of eastern Oregon. The Sierra Nevada Framework set forth a 20" diameter limit for tree cutting to conserve late-seral forests across national forest land in the Sierra Nevada. Larger diameter limit and exception-thresholds in these examples reflect more productive forests and larger mean diameters than in southwestern forests. Diameter limits in Region 3 forest plans restrict large tree cutting in habitat for Mexican spotted owl and northern goshawk for their viability and in "old growth"; diameter-based "vegetative structural stages" guide management of those species' habitats.

**Arguments Against Diameter Caps**

Arbitrary diameter thresholds (or "caps") may assure that trees of a certain size are retained, but they do not guarantee that short- or long-term ecological restoration goals will be achieved. In fact, diameter caps can actually prevent attainment of ecological restoration objectives because they can have unintended consequences such as interfering with the restoration of herbaceous openings and, where unnaturally dense stands of larger, post-settlement trees predominate, caps can limit fuel reduction and, therefore, undermine the agency's ability to re-establish surface fire (Abella et al. 2006, Sanchez-Meador 2009). A diameter threshold also creates a "one-size-fits-all" guideline which can lead to treatments that are inconsistent with site-based conditions.

In general caps are arbitrarily chosen to achieve socio-political objectives that do not necessarily support comprehensive ecological restoration. Contemporary diameter caps, even as an informal agreement, have become <u>the</u> condition that allows fuel reduction and restoration to move forward without lengthy delays due to appeals and litigation. Examples of their arbitrary application include:

- In order to test restoration treatments in the Grand Canyon, a 5-inch cap was required by environmental advocates (Fulé 2006).
- For restoration to proceed in the White Mountains, a 16-inch cap was required (Abrams and Burns 2007).
- A 12-inch cap was employed to define forest biomass appropriate for generating renewable energy (Arizona Corporation Commission, 2006).
- On the Coconino National Forest, a 16-inch cap was imposed to allow restoration projects proposed by the Grand Canyon Forest Partnership to proceed (Friederici 2003).

Further evidence that caps undermine ecological restoration goals is reflected in a recent decision on the Marshall Fuel Reduction and Forest Restoration Project (USFS 2010). The Forest Service rejected an alternative that proposed a 16-inch diameter cap because, "A 16-inch cap would prevent the restoration of natural openings and more natural spatial distribution of clumps of trees important for wildlife habitat and forest health." When administrative and legal challenges to forest thinning and restoration projects prevail it is generally because of issues related to agency compliance with law and policy (Brown 2009)—not because there is a scientific basis for a diameter threshold.

Finally, a static diameter cap fails to account for the fact that trees grow, that restoration will occur over decades while those trees are growing, and that over time, retention of excess trees may undermine efforts to restore ecosystem resilience in the face of drier conditions associated with climate change (Glicksman 2009, Westerling et al. 2006).

**Conclusions**

Recognizing a need to move beyond the historical debate and move forward with landscape-scale restoration that is ecologically, socially, and economically viable, the 4FRI Collaborative has agreed that the 4FRI effort should implement large tree retention and old growth protection strategies that are not based on strict diameter limits, but are based upon a 16” diameter threshold that limits the cutting of trees larger than 16” to circumstances and criteria set forth in pre-defined exception categories that follow. In addition, we are committed to monitoring the outcomes of treatments that follow this guidance to determine if they achieve our ecological restoration goals. If they do not we are committed to adapting this policy to achieve better ecological outcomes.

It is our hope and expectation that this approach will balance the approaches and opinions expressed above, and will serve as a policy mechanism for supporting comprehensive ecosystem restoration while addressing stakeholders’ needs for protecting old growth and large ponderosa pine trees.

## III. Exception Process for Large Post-Settlement Tree Retention

The following section outlines a problem statement, specific identifying circumstances, ecological objectives and selection criteria for instances in which large post-settlement trees may be cut to meet restoration objectives. At specific locations, large trees may need to be removed, felled, or girdled for purposes of ecological restoration and biodiversity conservation. The purpose of this section is to provide sufficient specificity to translate those exception categories—where stakeholder agreement exists to do so—into management actions and tree-marking guidelines. For eight of the nine exception categories programmatic recommendations describe the circumstances and criteria in which large post-settlement trees may need to be removed. For the "Heavily Stocked Stands with High Basal Area Generated by a Preponderance of Large Young Trees" (or "Large Young Tree") exception category, getting to a higher level of social and scientific agreement entails more complexity and challenges, so we propose the initiation of additional collaborative discussion and planning that we hope will bolster restoration efforts by increasing confidence and knowledge-sharing, maximizing agreement and minimizing disagreement.

# IV. Exceptions

## Seeps & Springs

**Suggested Tree Marking Exception Code**: "S"

**Identifiable Circumstance**

Seeps are locations where surface-emergent groundwater causes ephemeral or perennial moist soil or bedrock, where standing or running water is infrequent or absent and that exhibit vegetation and other biological diversity adapted to mesic soils.

Springs are small areas where surface-emergent groundwater causes ephemeral or perennial standing or running water, wet or moist soils and that exhibit vegetation and other biological diversity adapted to mesic soils or aquatic environments (Feth and Hem 1963).

**Problem Statement**

Seeps exhibit unique, often isolated biophysical conditions that can sustain unique, mesic-adapted biological diversity and can facilitate endemism and speciation. In the absence of frequent fires and in the presence of livestock grazing, large post-settlement trees may have established and grown in such proximity to seeps to compromise available soil moisture or light upon that afford those unique biophysical conditions.

Springs exhibit unique, often isolated biophysical conditions that can sustain unique, mesic-adapted or aquatic biological diversity and can facilitate endemism and speciation. Springs also provide water and other habitat to terrestrial wildlife. In the absence of frequent fires and in the presence of livestock grazing, large post-settlement trees may have established and grown in such proximity to springs to compromise available soil moisture (Simonin et al. 2007) or light upon that afford those unique biophysical conditions.

Removal of these trees may constitute a relatively small part of an overall seep and spring restoration effort when compared to addressing root causes of overall degradation. Thinning alone without addressing other sources of degradation is unlikely to restore seeps and springs (Thompson et al. 2002).

**Ecological Objectives**

(1) Conserve and restore the biophysical conditions in seeps and springs upon which terrestrial, mesic-adapted and aquatic native biological diversity depend.

**Criteria**

Large (>16"dbh) post-settlement ponderosa pine trees may be removed to conserve the unique biophysical attributes of seeps & springs according to these criteria:

(1) Where large trees' roots are encroaching on mesic soils associated with a seep or spring, or such trees' drip lines are overlapping or nearly overlapping a seep or spring such that its shading compromises the integrity of a spring's unique biophysical attributes, and;

(2) Where removing the trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

Note:
Where there is evidence of pre-settlement trees having grown in similar root and crown proximity to said seep or spring in the past, leave an equivalent number of large replacement trees.

## Riparian

**Suggested Tree Marking Exception Code:** "R"

**Identifiable Circumstance**

Riparian areas occur along ephemeral or perennial streams or are located down-gradient of seeps or springs. These areas exhibit riparian vegetation, mesic soils, and/or aquatic environments.

**Problem statement**

Riparian areas exhibit unique biophysical conditions that can sustain unique, mesic-adapted or aquatic biological diversity. Riparian areas and the streams, springs and seeps connected to them often harbor imperiled species and can be sources of endemism. Riparian areas also provide water and other habitat to terrestrial wildlife. In the absence of frequent fires and in the presence of livestock grazing, water development projects and other factors, large post-settlement trees may have established and grown within riparian areas such that they compromise available soil moisture or light that support those unique biophysical conditions. However, it is likely to be a very rare circumstance that trees of any size will need to be removed from forested riparian zones.

Cutting of any trees within riparian areas should minimize impacts by following Best Management Practices (BMPs).

Whenever possible, large trees identified for cutting should be left onsite as snags or downed logs.

Removal of these trees may constitute a relatively small part of an overall riparian area restoration effort when compared to addressing fundamental causes of overall degradation. Thinning alone without addressing other sources of degradation is unlikely to restore riparian areas.

**Ecological Objectives**

Conserve and restore the biophysical conditions in riparian habitat upon which terrestrial and aquatic native biological diversity depend.

**Criteria**

Large (>16"dbh) post-settlement ponderosa pine trees may be removed to conserve the unique biophysical attributes of riparian areas according to these criteria:

(1) Where large trees are growing (rooted) within a riparian area and compromising available soil moisture or light that support that area's unique biophysical conditions, and

(2) Where removing the trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

Notes:
Where there is evidence of pre-settlement trees having grown in similar root and crown proximity to said riparian in the past, leave an equivalent number of large replacement trees.

There may be additional areas and/or circumstances identified for riparian restoration through a site specific agreement-based, collaborative process as described in the 4FRI Charter.

# Wet Meadows

**Suggested Tree Marking Exception Code**: "WM"

**Identifiable Circumstance**

High-elevation streamside or spring-fed meadows occur in numerous locations throughout the Southwest. However, less than 1% of the landscape in the region is characterized as wetland (Dahl 1990), and wet meadows are just one of several wetland types that occur. Patton and Judd (1970) reported that approximately 17,700 ha of wet meadows occur on national forests in Arizona and New Mexico.

These areas may be referred to as riparian meadows, montane (or high-elevation) riparian meadows, sedge meadows, or simply as wet meadows. Wet meadows are usually located in valleys or swales, but may occasionally be found in isolated depressions, such as along the fringes of ponds and lakes with no outlets. Where wet meadows have not been excessively altered, sedges (*Carex* spp.), rushes (*Juncus* spp.), and spikerush (*Eleocharis* spp.) are common species (Patton and Judd 1970, Hendrickson and Minckley 1984, Muldavin et al. 2000). Willow (Salix) and alder (Alnus) species often occur in or adjacent to these meadows (Long 2000, 2002, Maschinski 2001, Medina and Steed 2002). High-elevation wet meadows frequently occur along a gradient that includes aquatic vegetation at the lower end and mesic meadows, dry meadows, and ponderosa pine or mixed conifer forest at the upper end. These vegetation gradients are closely associated with differences in flooding, depth to water table, and soil characteristics (Judd 1972, Castelli et al. 2000, Dwire et al. 2006). While relatively rare, wet meadows are believed to be of disproportionate value because of their use by wildlife and the range of other ecosystem services they provide. Wet meadows perform many of the same ecosystem functions associated with other wetland types, such as water quality improvement, reduction of flood peaks, and carbon sequestration.

**Problem statement**

Wet meadows are one of the most heavily altered ecosystems. They have been used extensively for grazing livestock, have become the site of many small dams and stock tanks, have had roads built through them, and have experienced other types of hydrologic alterations, most notably the lowering of their water tables due to stream downcutting, surface water diversions, or groundwater withdrawal (Neary and Medina 1996, Gage and Cooper 2008). In the presence of livestock grazing and hydrologic changes, large post-settlement trees may have established and grown within wet meadows such that they compromise available soil moisture or light creating unique biophysical conditions.

Removal of these trees may constitute a relatively small part of an overall wet meadow restoration effort when compared to addressing root causes of overall degradation. Thinning alone without addressing other sources of degradation is unlikely to restore wet meadows.

**Ecological Objectives**

Conserve and restore the biophysical conditions of wet meadows upon which terrestrial native biological diversity depend.

**Criteria**

Large (>16”dbh) post-settlement ponderosa pine trees may be removed to conserve the unique biophysical attributes of wet meadows according to these criteria:

(1) Where large trees are growing (rooted) in a wet meadow, and

(2) Where removing the trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

Note:
Where there is evidence of pre-settlement trees having grown in similar root and crown proximity to said wet meadows in the past, leave an equivalent number of large replacement trees.

## Encroached Grasslands

**Suggested Tree Marking Exception Code**: "EG"

**Identifiable Circumstance**

Encroached grasslands are herbaceous ecosystems that have infrequent-to-no evidence of pine trees growing prior to settlement. The two prevalent grassland categories in the 4FRI landscape are montane (includes subalpine) grasslands and Colorado Plateau (a subset of Great Basin) grasslands, with montane grasslands being most common (Finch 2004). A key indicator of grasslands is the presence of mollisol soils, which are typically deeper with higher rates of accumulation and decomposition of soil organic matter relative to soils in the surrounding landscape. Grasslands in this region evolved during the Miocene and Pliocene periods, and the dark, rich soils observed in grasslands today have taken more than 3 million years to produce. In addition to their association with mollic soils, grasslands in this region are maintained by a combination of climate, fire, wind desiccation, and to a lesser extent by animal herbivory (Finch 2004).

Typical montane grasslands in this region are characterized by Arizona fescue (Festuca arizonica) meadows on elevated plains of basaltic and sandstone residual soils. Montane grasslands are the most naturally fragmented grasslands in the region, ranging from thousands of acres in size (e.g., in the White Mountains, Baker 1983) down to only a few acres. They generally occur in small (<100 ac.) to medium-sized (100 to 1000 ac.) patches. Historic maintenance of the herbaceous condition in these grasslands is subject to some debate though appears to be primarily driven by periodic fire. The cool-season growth of Arizona fescue also plays a large role in maintenance of parks and openings by directly competing with ponderosa pine seedlings.

Identification of grasslands in this region should use a combination of the Terrestrial Ecosystem Survey, Southwest Regional GAP Analysis, Brown and Lowe Vegetation Classification (Brown and Lowe 1982; TNC GIS Layer 2006) among other existing vegetation and soils data.

This exception category will require an iterative process of collaborative mapping, field verification, and refinement. There are some debate and questions about where and how much the grassland-forest mosaic shifts over time and space. There are also debate and questions about whether some recently-burned areas are early seral forests or stable grasslands, whether or how they may be surrogates for historical grasslands, and if or how that should factor into the overall retention of forest cover. Recognizing the importance of montane grassland restoration, we encourage all parties to seek resolution to these issues on a case-by-case basis through field visits, literature review, and/or discussion.

**Problem statement**

Prior to European settlement, pine trees rarely established in grasslands because they were either outcompeted by production of cool-season grasses or killed by frequent fire (Finch 2004). In the late 1800s, unsustainable livestock grazing practices significantly reduced herbaceous cover, releasing competition pressure on pine seedlings. Coupled with the onset of fire suppression in the early 1900s, pine trees rapidly encroached and recruited into native grasslands (e.g., Allen 1984, Moore and Huffman 2004, Coop and Givnish 2007).Pine encroachment into grasslands has contributed to a significant loss of biodiversity (Stacey 1995) and wildlife habitat particularly for grassland-dependent species such as pronghorn. Plant diversity is particularly important in grassland ecosystems: grassland plots with greater specie diversity have been found to be more resistant to drought and to recover more quickly than less diverse plots (Tilman and Downing 1994); this resilience will become even more important in a warming climate. Pine tree removal, restoration of fire, and complementary reductions in livestock grazing pressure are all necessary to restore structure and function of native grasslands.

**Ecological Objectives**

(1) Enhance, maintain, and restore naturally functioning grasslands.

(2) Ensure native grassland composition, increase native species diversity, improve resilience to drought.

(3) Restore natural fire regime.

**Criteria**

Large (>16” dbh) post-settlement ponderosa pine trees may be cut and/or removed to restore the unique biophysical attributes of grasslands according to these criteria:

(1) Where existing grasslands are being encroached, and large trees are interfering with overall restoration objectives, and

(2) Where removing the trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

There may be additional areas and/or circumstances identified for grassland restoration through a site specific agreement-based, collaborative process as described in the 4FRI Charter.

# Aspen Forest & Woodland

**Suggested Tree Marking Exception Code:** "AF"

**Identifiable Circumstance**

Quaking aspen (*Populus tremuloides*) occurs in small patches throughout the 4FRI area. Bartos (2001) refers to three broad categories of aspen: (1) stable and regenerating (stable), (2) converting to conifers (seral), and (3) decadent and deteriorating. Almost all of the aspen within ponderosa pine of the 4FRI area occurs as seral aspen, and regenerates after disturbance. Favorable soil and moisture conditions maintain stable aspen over time.

**Problem Statement**

Aspen occurs within ponderosa pine forests, and is ecologically important due to the high concentration of biodiversity that depends on aspen for habitat (Tew 1970, DeByle 1985, Finch and Reynolds 1987, Griffis-Kyle and Beier 2003). In addition, stable aspen stands serve as an indicator of ecological integrity (Di Orio and others 2005). However, aspen is currently declining at an alarming rate (Fairweather and others 2008).

The loss of fire as a natural disturbance regime in southwestern ponderosa pine forests since European settlement has caused much of the aspen-dominated lands to succeed to conifers (Bartos 2001). Other factors contributing to gradual aspen decline over the past 140 years include reduced regeneration from browsing by livestock and introduced and native wild ungulates in the absence of natural predators like wolves (Pearson 1914, Larson 1959, Martin 1965, Jones 1975, Shepperd and Fairweather 1994, Martin 2007). More recently, aerial and ground surveys indicate more rapid decline of aspen, with 90% mortality occurring in low elevation aspen sites and over 60% mortality observed in mid-elevations. Major factors thought to be causing this rapid decline of aspen include frost events, severe drought, and a host of insects and pathogens (Fairweather and others 2008) that have served as the "final straws" for already compromised stands.

Removal of encroaching pine trees constitutes part of an overall aspen restoration effort. Thinning alone without addressing other sources of degradation, such as excessive herbivory is unlikely to successfully restore aspen forests.

Some stakeholders expressed that considerable uncertainty exists around fire regimes for aspen in ponderosa pine, and that research questions remain unanswered around the prevalence of mixed-severity fire and its ecological role as a driving force for aspen stands at the top of its elevational range, and on steep slopes within this vegetation type.

**Ecological Objectives**

(1) Conserve and restore aspen forests and woodlands within 4FRI area by restoring appropriate fire regimes and decreasing competition from ponderosa pine.

(2) Protect regeneration, saplings, and juvenile trees from browsing.

**Criteria**

Large (>16"dbh) post-settlement trees may be cut in conifer-encroached seral aspen stands according to the following criteria:

(1) Where current post-settlement ponderosa pine tree numbers are above and beyond residual targets (identified using pre-settlement conifer tree evidences), and

(2) Where fire cannot be used safely and effectively to regenerate or maintain aspen, or

(3) Where site visitation and/or data collection and analysis indicates the need for encroachment mitigation, and

(4) Where removing large trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat

Note:
There may be additional areas and/or circumstances identified for aspen restoration through a site specific agreement-based, collaborative process as described in the 4FRI Charter.

# Ponderosa Pine/Gambel Oak Forest (Pine-Oak)

**Suggested Tree Marking Code**: “P-O”

**Identifiable Circumstance**

A number of habitat types exist in the southwestern United States that could be described as pine-oak. Ponderosa pine forests are interspersed with Gambel oak trees in locations throughout the 4FRI area in a habitat association referred to as PIPO/QUGA (USFS 1997, USDI FWS 1995). Specifically, any stand within the Pinus ponderosa series where ≥10% of stand basal area consists of Gambel oak (*Quercus gambelii*) ≥13 cm (5 in) diameter at root collar (drc) is considered to be pine-oak within the 4FRI area (USDI FWS 1995). In southwestern ponderosa pine forests, Gambel oak has several growth forms distinguished by stem sizes and the density and spacing of stems within clumps. These include shrubby thickets of small stems, clumps of intermediate-sized stems, and large, mature trees that are influenced by age, disturbance history, and site conditions (Brown 1958, Kruse 1992, Rosenstock 1998, Abella and Springer 2008, Abella 2008a). Different growth forms provide important habitat for a large number of varying wildlife species (Neff and others 1979, Kruse 1992).

Gambel oak provides high quality wildlife habitat in its various growth forms, and is a desirable component of ponderosa pine forests (Neff and others 1979, Kruse 1992, Bernardos et al. 2004). Gambel oak enhances soils (Klemmedson 1987), wildlife habitat (Kruse 1992, Rosenstock 1998, USDI FWS1995, Bernardos et al. 2004), and understory community composition (Abella and Springer 2008). Large oak trees are particularly valuable since they typically provide more natural cavities and pockets of decay that allow excavation and use by cavity nesters than conifers. In addition to its important ecological role, Gambel oak has high value to humans as it is a popular fuelwood that possesses superior heat-producing qualities compared to other tree species (Wagstaff 1984).

**Problem Statement**

Although management on public lands with regard to oak has changed to better protect the species, illegal fuelwood cutting of Gambel oak and elk and livestock grazing negatively impact oak growth and regeneration (Harper et al. 1985, Clary and Tiedemann 1992, Rick Miller, 1993, unpublished report) and continues to result in the removal of rare, large diameter oak trees (Bernardos et al. 2004).

A literature review by Abella and Fule (2008) found that Gambel oak densities appear to have increased in many areas with fire exclusion, especially in the small and medium-diameter stems (<8” dbh). Chambers (2002) found that Gambel oak on the Kaibab and Coconino National Forests was distributed in an uneven-aged distribution, dominated by smaller size classes (<5 cm dbh) and few large diameter oak trees. Because of Gambel oak's slow growth rate, there may be little opportunity for these small Gambel oak trees to attain large diameters (>85 cm) (Chambers 2002).

Pine competition with oak has been identified as an issue in slowing oak growth, particularly for older oaks (Onkonburi 1999). Onkonburi (1999) also found that for northern Arizona forests, pine thinning increased oak incremental growth more than oak thinning and prescribed fire. Fule (2005) found that oak diameter growth tended to be greater in areas where pine was thinned relative to burn only treatments and controls. Thinning of competing pine trees may promote large oaks with vigorous crowns and enhanced acorn production (Abella 2008b), and may increase oak seedling establishment (Ffolliott and Gottfried 1991).

**Ecological Objectives:**

(1) Maintain and restore all growth forms of Gambel oak, focusing on enhancing and maintaining larger, older oak trees.

(2) Restore frequent, low intensity surface fire to ponderosa pine-Gambel oak forests.

(3) Restore and maintain brushy thicket, pole and dispersed clump growth forms of Gambel oak by allowing natural self-thinning, thinning dense clumps, and/or burning.

(4) Protect Gambel oak growth forms from fuel wood cutting, damage during restoration treatments including thinning and post thinning slash burning.

**Criteria**

In pine-oak, which occurs when $\geq$10% of the stand basal area consists of Gambel oak >13 cm (5 in) diameter at root collar, large (>16 dbh) post-settlement ponderosa pine trees may be removed to conserve oaks according to these criteria:

*In MSO restricted habitat*:

(1) Within MSO habitat and designated critical habitat, the Recovery Plan for the Mexican spotted owl should be followed to improve key habitat components and primary biological factors, which includes Gambel oak, or

*Outside MSO restricted habitat*: where large post-settlement trees' drip lines or roots overlap with those of Gambel oak trees exhibiting drc of >12"; and

(2) Where removing the trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

## Within Stand Openings

**Suggested Tree Marking Exception Code**: "WSO"

**Identifiable Circumstance**

Within Stand Openings are small openings (generally 0.05 to 1.0 acres) that were occupied by grasses and wildflowers before settlement (Pearson 1942, White 1985, Covington and Sackett 1992, Sanchez-Meador et al. 2009). Pre-settlement openings can be identified by the lack of stumps, stump holes, and other evidence of pre-settlement tree occupancy (Covington et al. 1997). These openings are most pronounced on sites with heavy textured (e.g., silt-clay loam) soils (Covington and Moore 1994). Current openings include fine scaled canopy gaps. It is not necessary that desired within stand openings and groups be located in the same location that they were in before settlement (the site fidelity assumption). Trees might be retained in areas that were openings before settlement, and openings might be established in areas which had previously supported pre-settlement trees. The within stand opening criteria described here are distinct from and should not be considered as guidance relating to regeneration openings. The stakeholder group does not support the cutting of large trees to create regeneration openings.

**Problem Statement**

Within stand openings appear to have been self-perpetuating before overgrazing and fire exclusion (Pearson 1942, Sanchez-Meador et al. 2009). Fully occupied by the roots of grasses and wildflowers as well as those of neighboring groups of trees, these openings had low water and nutrient availability because of intense root competition (Kaye et al. 1999). Heavy surface fuel loads insured that tree seedlings were killed by frequent surface fires, reinforcing the competitive exclusion of tree seedlings (Fulé et al. 1997). These natural openings appear to have been very important for some species of butterflies, birds, and mammals (Waltz and Covington 2004). Often the largest post-settlement trees, typically a single tree, became established in these natural within a stand opening as soon as herbaceous vegetation was removed by overgrazing (Sanchez-Meador et al. 2009). Contemporary within stand openings or areas dominated by smaller post-settlement trees should be the starting point for restoring more natural within stand heterogeneity.

**Ecological Objectives**

(1) Conserve and restore openings within stands to provide natural spatial heterogeneity for biological diversity.

(2) Break up fuel continuity to reduce the probability of torching and crowning.

(3) Restore natural heterogeneity within stands.

(4) Promote snow-pack accumulation and retention to benefit groundwater recharge and watershed processes at small scale.

**Criteria**

Large (>16” dbh) post-settlement ponderosa pine trees may be removed to restore the unique biophysical attributes of within stand openings according to these criteria:

(1) When the presence of such trees would prevent the re-establishment of sufficient within stand openings to emulate natural vegetation patterns based on current stand conditions, pre-settlement evidences, desired future conditions, or other restoration objectives, and

(2) Where desired openings are tentatively identified as ≥0.05 acre (these openings should be established wherever possible by enlarging current within stand openings or where small diameter trees are predominant), and

(3) Where removing the trees does not conflict with existing recovery/conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

NOTE: It is not necessary that within stand openings and groups be located in the same location that they were in before settlement. That is, trees might be retained in areas that were openings before settlement, and openings might be established in areas that had previously supported pre-settlement trees.

## [2]Heavily Stocked Stands with High Basal Area Generated By a Preponderance of Large Young Trees

**Suggested Tree Marking Exception Code**:  "LYT"

**Identifiable Circumstance**
In some areas irruption of post-settlement has been so robust that current stand structure is characterized by high density and basal area of large, young ponderosa pine trees. These stands or groups of stands exhibit continuous canopy promoting unnaturally severe fire effects under severe fire weather conditions.  At the small scales, this circumstance applies on a case-by-case basis where the cutting of large trees is necessary to meet site-specific ecological objectives such as reducing potential for crown fire spread into communities or important habitats such as for Mexican spotted owls and/or goshawk nest stands.  This circumstance applies where other exception categories, when implemented, would not alleviate the afore-mentioned severe fire effects.

**Problem Statement**
In stands where pre-settlement evidences, restoration objectives, community protection, or other social or ecological restoration objectives indicate much lower tree density and BA would be desirable, large post-settlement pines may need to be removed to achieve post-treatment conditions consistent with a desired restoration trajectory. In stands where evidences indicate that higher tree density and BA would have occurred pre-settlement, only a few large pines may need to be removed. Many of these areas would support crown fire, and thus require structural modification to reduce crown fire potential and restore understory vegetation that supports surface fire.

**Ecological Objectives**

Natural heterogeneity of forest, savannah and grasslands occurs at the landscape scale.

Natural heterogeneity exists within stands.

Canopy fuel discontinuity reduces the probability of torching and crowning and restores herbaceous fuel continuity to carry surface fire.

Natural fire (rather than silviculture) is the principle regulator of forest structure over time.

Restore groups by retaining the largest trees on the landscape to most quickly re-establish old growth structure, where appropriate to site conditions, restoration and species conservation objectives.

[2] The "Large Young Tree" exception was drafted, vetted with the Stakeholder Group, finalized and submitted to the USFS on July 15, 2011.

**Criteria**

Large (>16" dbh) post-settlement ponderosa pine trees may be removed to meet restoration objectives according to these criteria:

(1) When the presence of such trees contributes to continuous canopy promoting unnaturally severe mid- or larger-scale (100+ acre) fire effects under severe fire weather conditions;

(2) When the cutting of such trees is necessary to meet site-specific social or ecological objectives such as reducing potential for crown fire spread into communities or important habitats such as for Mexican spotted owls and/or goshawk nest stands;

(3) When other exception categories, if implemented, would not alleviate the afore-mentioned severe fire effects;

(4) When removing the trees does not conflict with existing recovery / conservation plan objectives for managing sensitive, threatened or endangered species or their habitat.

Note: It is not necessary that trees or groups be located in the same location that they were in before settlement. That is, trees might be retained in areas that were openings before settlement, and openings might be established in areas that had previously supported pre-settlement trees.

## V. Description of Desired Next Steps and Ongoing Collaborative Clarification of OGP&LTRS

All of the exception categories listed in this document have been clarified such that they can be operationalized "programmatically", that is, the process of mapping and selecting areas for exceptions is ready to be tested with real data in specific areas. This means that the stakeholder group considers the guidance offered for these exception categories sufficient to operationalize large tree retention/removal per these criteria across the 4FRI area. This process will require the participation of stakeholders and USFS team members to ensure that the suggested process in this document achieves the stated restoration objectives, and is not burdensome in its approach and mechanics.

[3]The "Large Young Tree" exception category listed in this document will require additional collaborative analysis and clarification. Thus far, the group has discussed an opportunity and a need to carry these discussions forward with a combination of additional site visits to representative areas, analysis of USFS stand data, and further exploration of ForestERA remote sensing data that could inform our collective sense of the distribution and extent of areas exhibiting circumstances necessitating large tree removal, and an efficient means of analyzing data and selecting areas for treatment.

Recognizing the importance of finding additional clarity and agreement for these exception categories, the group intends to pursue additional field and data-centered explorations of these exception categories in 2011, working closely with the Forest Service to ensure that additional analysis occurs in a coordinated fashion, and that additional recommendations can be operationalized in a straightforward fashion. Analysis and visitation schedules are intended to be developed by March, 2011, and completed by May 6, 2011.

[3] The "Large Young Tree" exception was drafted, vetted with the Stakeholder Group, finalized and submitted to the USFS on July 15, 2011.

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## Appendix 1 – Reservations

From Scott Harger, Coconino NRCD

From: Scott Harger [mailto:cannonbone@msn.com] Sent: Friday, March 04, 2011 6:57 PM To: Windy Greer Subject: Re: Old Growth Protection and Large Tree Retention Strategy Document for Stakeholders' review

Dear Windy, and LTRS Sub-Group of the LSWG:

I appreciate the accelerated effort to push this document for timely delivery to the USFS.

I like the descriptions captured here for the large tree strategy overview and rationale for the document and the 8-of-9 exception categories whose language appear to be resolved. Except for some very turgid prose in section V that can be edited, I can support this draft as a partial or preliminary version, subject to review of the 9th exception. Otherwise, I can support approval of this final draft without conditions. I would also support it if "Problem Description" were changed to "Management Issue" or "Concerns driving the Exception" or something that doesn't suggest that habitats are problems.

Scott Harger
Range Conservationist
Coconino NRCD
Flagstaff, AZ
928.527.9050

From Scott Hunt, Arizona State Forester

From: Scott Hunt [mailto:ScottHunt@azsf.gov] Sent: Friday, March 11, 2011 12:00 PM To: Windy Greer; 'Ethan Aumack'; Ed Smith Cc: Kevin Boness Subject: RE: Old Growth Protection and Large Tree Retention Strategy Document for Stakeholders' review

Thank you Ed and Ethan for the dedicated work on this strategy. The State Forestry Division agrees with reservations on this large tree retention policy. The arguments against diameter caps that you provided in the policy capture most of our reservations. We have two additional items we wish to offer for consideration:

-In the category “Seeps and Springs” under criteria: there should be an allowance for removal of large trees a considerable distance from the seep or spring to help invigorate infiltration and flow. Distance will need to be determined by the effective area that benefits the seep or spring.

-We believe a consideration needs to given for stands that may have a healthy understory of regenerated ponderosa pine with an overstory of trees that are heavily infected with dwarf mistletoe. Objectives for this type of stand may encourage and favor the vigorous, healthy understory. Removal of the larger trees that are infected would be required to meet the stand objectives.

We will look forward the opportunity to comment on the Larger Young Tree removal category when it is developed. Thanks again for all your time and effort.

Scott Hunt

ITEM C:

Most recent 4FRI "SPLYT" Agreement

# Four Forest Restoration Initiative (4FRI) Stakeholder Group

## UPDATE to August 2017 Stakeholder Position Statement: Planning for Stands with a Preponderance of Large Young Trees (SPLYT)

At the September 2017 4FRI Stakeholder Group meeting, stakeholders re-visited the need for utilizing Site Class filters to determine SPLYT stand management. Full consensus was reached to remove all Site Class filters for such analyses. Please consider the following statement the final position of the 4FRI Stakeholder Group:

The iterative spatial analysis and field validation effort undertaken by the 4FRI Team and stakeholders yielded an initial filter for SPLYT stands located outside of Mexican Spotted Owl (MSO) Protected Activity Centers, MSO Recovery Habitat, and wildland urban interfaces (WUI). SPLYT criteria are: a) Quadratic Mean Diameter (QMD) of the largest 20 trees is >15" and b) there is >50 square feet/acre of basal area (BA) in trees >16" diameter at breast height (DBH). All stands will be field-verified prior to mechanical thinning. Stands (or portions thereof) meeting SPLYT criteria, including those not captured by the data filter, will be treated at the lowest range of intensity. For example, a stand identified with the flexible toolbox to receive a Uneven-aged treatment with 10 to 25% interspace (UEA 10-25) treatment would be treated to 10% interspace and to the upper end of Natural Range of Variability (NRV) for trees per acre (TPA) and BA in order to maintain large tree dominance and conditions favorable to canopy-dependent species. Stands (or portions thereof) that are captured by the SPLYT criteria data filter but upon field verification are determined not to meet the SPLYT criteria will be treated within the range of intensities applied to other non-SPLYT stands.

Statement approved by unanimous 4FRI Stakeholder Group consensus on September 27, 2017 and provided to U.S.D.A. Forest Service 4FRI Board and Planning Team on October 13, 2017.

Sue Sitko

Sue Sitko
Co-Chair, 4FRI Stakeholder Group

Diane J. Vosick

Diane Vosick
Co-Chair, 4FRI Stakeholder Group

ITEM D:

Center for Biological Diversity Objection Letter to West Escudilla Restoration Project

***Via Web***
June 16, 2017
Calvin Joyner, Regional Forester
USDA Forest Service
333 Broadway SE
Albuquerque, NM 87102
Email: objections-southwestern-apache-sitgreaves@fs.fed.us
**RE: Corrected Objection to West Escudilla Forest Restoration Project**

Pursuant to 36 C.F.R. § 218, the Center for Biological Diversity ("Center") objects to the draft Decision Notice ("DN") for the West Escudilla Forest Restoration Project ("project") in the Alpine Ranger District of the Apache-Sitgreaves National Forests. On Oct. 7, 2015, the Center supplied timely written comment on a proposed action for the project. Also, the Center provided the Forest Service with timely written comment on the draft Environmental Assessment ("EA"). Previously, The Center may object per § 218.5. Legal notice of opportunity to object published in the *White Mountain Independent* newspaper and based on personal communications with the Forest Supervisor and Deputy Forest Supervisor the deadline for objection is June 16, 2017. Therefore, this objection is timely.

**Project name:** West Escudilla Forest Restoration Project
**Deciding official:** Forest Supervisor, Apache-Sitgreaves National Forests
**Project location:** Alpine Ranger District
**Proposed decision:** Proposed activities include vegetation treatments, prescribed fire, aquatic, and watershed activities on approximately 66,000 acres, including substantial acreage of group selection and intermediate thinning in Northern Goshawk PFA's and foraging habitat and shelterwood cutting in NGH foraging areas to deal with mistletoe.

**Objector: Center for Biological Diversity**
P.O. Box 710
Tucson, AZ 85702
Tel: (928) 853-9929
Email: tschulke@biologicaldiversity.org

**Objector's interest**
The Center is a non-profit, public interest organization headquartered in Tucson, Arizona, representing more than 50,000 members, many of whom reside in Arizona and maintain interests in the Apache-Sitgreaves National Forests. The Center's mission is to conserve and recover imperiled fauna and flora and their habitats through science, education, policy and law.
Members of the Center regularly use and enjoy, and will continue to use and enjoy the national forest lands located in the project area for observation, research, aesthetic enjoyment and other recreational, scientific and educational activities. Members of the Center will continue to research, study, observe

and seek protection for at-risk species associated with natural habitats found in the project area because they derive scientific, educational, conservation and aesthetic benefits from the existence of the full complement of native biological diversity found in the wild places of Arizona. Forest Service violations of law and policy in the project may cause significant adverse impacts to threatened and sensitive species and/or indicator species whose viability is of management concern. Agency violations of law and policy may degrade native vegetation and soil or habitat, food resources or populations of species whose viability the Forest Service is obligated to maintain. Direct, indirect or cumulative impacts of the project to the environment may harm the interests of the Center and its members in the conservation of nature and the recovery of wildlife.

**Resolution**
The reviewing officer may determine whether to discuss resolution. 36 C.F.R. § 218.11.
Either the reviewing officer or the objector "may request to meet" and discuss resolution. *Id*.
The Center will consider a request from the reviewing officer to meet and discuss this objection.
In our view, a final decision implementing the project should:

1. Include updated language developed by the 4FRI Stakeholders Group designed to protect stands with mature/OG characteristics valuable to canopy dependent species (known as SPLYT stands - stands with a preponderance of large young trees). "SPLYT" stands are currently identified as those with a QMD of top 20 trees greater than 15" and 50BA or greater in trees 16" and larger on Site Class 1. These stands would receive treatment, where necessary, from least intensive prescriptions from the variety of prescriptive approaches proposed in the draft EA, in order to maintain large tree structure and higher levels of canopy cover.
2. Utilize alternative mistletoe treatment approaches being developed with the 4FRI Stakeholders Group that avoid overstory removal and removal of large and old growth trees.

**Reasons**
1. Including the "SPLYT" language offers clarification in response to comments and concerns addressing large tree protection and wildlife habitat protection. Additionally, including this language will bring the West Escudilla Restoration project in line with the mandate from the CFLRA to maximize the protection of large trees and help build consensus amongst the stakeholders group allowing agreement to include West Escudilla on the list of projects the stakeholders support for CFLRA funding.
2. Including the developing approach for addressing mistletoe offers clarification in response to comments and concerns addressing overstory removal and the protection of large and old trees. Additionally, including this language will bring the West Escudilla Restoration project in line with the mandate from the CFLRA to maximize the protection of large trees and help build consensus amongst the stakeholders group allowing agreement to include West Escudilla on the list of projects the stakeholders support for CFLRA funding.

Thank you for considering this objection. You may contact me at the email address or phone listed below.
Todd Schulke
707 N. Black St.
Silver City, NM, 88071
Tel: 575.574.5962
Email: tschulke@biologicaldiversity.org

ITEM E:

Deputy Regional Foresters Resolution Letter for the Centers West Escudilla Objection

USDA United States Department of Agriculture | Forest Service | Southwestern Region Regional Office

333 Broadway SE
Albuquerque, NM 87102
505-842-3292
Fax: 505-842-3800

File Code: 1570
Date: JUL 3 1 2017

Todd Schulke
Center for Biological Diversity
P.O. Box 710
Tucson, AZ 85702

Dear Mr. Schulke:

On June 15, 2017, you filed an objection on behalf of the Center for Biological Diversity (CBD) to the West Escudilla Restoration Project Final Environmental Assessment (EA) and Draft Decision Notice (DN) released by the Forest Supervisor of the Apache-Sitgreaves National Forests, Michael S. Best.

As a result of the objection resolution meeting held on July 14, 2017, we were able to reach an agreement to resolve your issues. On July 26, 2017, an Objection Resolution Agreement (enclosed) documenting specific actions to be taken by the Apache-Sitgreaves National Forests was signed by you, on behalf of CBD, and the Forest Supervisor. The resolution included an agreement by CBD to withdraw their objection. You formally withdrew your objection by letter on July 26, 2017, (enclosed).

In accordance with the regulation at 36 CFR 218(a)(6), I am setting aside your objection from further review. I appreciated the opportunity to discuss CBD's concerns with you. The open, candid discussions allowed us to focus on those areas where we were able to come to some resolution on the issues raised in your objection. Your input and participation have been extremely valuable in helping the agency make a more informed decision.

Sincerely,

SANDRA WATTS
Deputy Regional Forester

Enclosure

cc: Steve Best; Wendy Jo Haskins; Tim Gilloon; Sheila Williams; Blair Halbrooks

**West Escudilla Restoration Project**

**Apache-Sitgreaves National Forests**

**Objection Resolution Agreement**

On May 2, 2017, the Forest Supervisor of the Apache-Sitgreaves National Forests, Michael S. Best, released the West Escudilla Restoration Project Final Environmental Assessment (EA) and Draft Decision Notice (DN). On June 15, Todd Schulke filed an objection on behalf of the Center for Biological Diversity (CBD).

On July 14, 2017, Michael S. Best (Responsible Official) and Deputy Regional Forester Sandra Watts (Objection Reviewing Official) met with Todd Schulke to explore opportunities to resolve the objection. Both parties acknowledged that they are likely looking for similar outcomes in the implementation of this project. The parties agreed that the treatment of large young trees could be done at the least-intensive range within that prescription in order to maintain a higher density of large trees. In addition, they acknowledged there is flexibility for treatment options aimed at ensuring adequate healthy regeneration, lessening long-term impacts from dwarf mistletoes (DM), and increasing long-term forest health and resiliency while maintaining healthy or lightly DM infected large and old trees within these areas. As a result of this discussion, we were able to resolve CBD's objection issues by agreeing to take the following actions:

- Incorporate language in the DN that affirms treatment of Stands with a Preponderance of Large Young Trees (SPLYT) at the least intensive range of management within that prescription.
- Incorporate language in the DN that allows for the creation of prescriptions in DM infected areas in a manner that mimics desired conditions of groups and varying age classes, especially older and/or larger trees.
- Collaborate with CBD in the field and in office meetings to review and discuss the variety of prescriptions and monitoring in West Escudilla that primarily deal with the 580+ acres of severe DM infected stands (80% or greater is at the 4-6 DMR range) that will receive regeneration treatments. These discussions may focus on pre- and post-treatments, pre- and post-conditions, what may work, what did work, and what may be appropriate options for the future in other areas.

As part of this agreement and objection resolution, CBD agrees to withdraw its objection in whole.

Todd Schulke, Center for Biological Diversity — Date

Wendy Jo Haskins for — 07/25/2017

Michael S. Best, Forest Supervisor — Date

ITEM F:

4FRI Stakeholders Group letter to 4FRI Executive Team rejecting aggressive Mistletoe treatments http://www.4fri.org/

April 27, 2017

USFS 4FRI Chief Executive Scott Russell
sarussell@fs.fed.us

Re: 4FRI Stakeholder Group Position on Dwarf Mistletoe Treatments in the Rim Country EIS.

Dear Scott,

On April 5, 2017, members of the U.S. Forest Service (USFS) 4FRI ID Team gave a presentation to the 4FRI Planning Workgroup (PWG) on dwarf mistletoe concerns in the Rim Country EIS planning area. It included a review of the role of dwarf mistletoe in forest ecosystems, an assessment of historical and current mistletoe infection levels, and a proposal for aggressive, targeted treatments (aka "mitigation") in moderately to severely infected stands (>20% of area infected; up to 265,000 acres of the planning area under current Forest Plan direction). This "mitigation" approach was included in the Proposed Action prepared by the USFS. It was asserted that a failure to implement dwarf mistletoe "mitigation" would be contrary to direction in the Forest Plans.

The PWG evaluated the information presented by USFS and developed this recommendation for consideration by the 4FRI Stakeholder Group (SHG), and with its approval, communication to USFS. The SHG decided unanimously to adopt this recommendation at its April 26, 2017 meeting.

The SHG appreciated the Forest Service's outreach to the PWG and concurs with the stated goal of maintaining mistletoe as a natural component of restored forests. Dwarf mistletoe is a natural disturbance agent and component of coniferous forests within the planning area. The plant provides food and cover for wildlife; large-tree mortality caused by mistletoe is an important factor in recruiting snags that provide habitat for cavity-nesting birds and other species.

The historical and recent data presented by USFS did not make a compelling case that mistletoe infections within the planning area are significantly outside the natural range of variability and pose a meaningful obstacle to meeting restoration objectives. The SHG welcomes additional data that USFS can bring to bear on this issue and the opportunity to see first-hand examples on the ground. We are also greatly interested in the larger discussion about using restoration treatments to address forest health concerns related to dwarf mistletoe.

The SHG feels that restoration treatments consisting of mechanical or hand thinning, followed by application of prescribed/managed fire at regular intervals, meet the intent of the Forest Plans and are the preferred approach for stands with high levels of mistletoe infection. Where needed, those stands could also be buffered to reduce mistletoe spread. The SHG also supports testing alternative restoration treatments for affected stands, if done at limited scale and in a learning/adaptive management framework.

The SHG also feels that traditional silvicultural approaches to managing dwarf mistletoe (e.g. overstory removal, even-aged management) are inconsistent with an ecological restoration approach and are not supported by the best available science. These may also be at odds with directions in 4FRI stakeholder foundational documents; the Collaborative Forest Landscape Restoration Program; and, the 2012 USFS Planning Rule. The SHG is particularly concerned that alternatives containing such aggressive treatments will be controversial and likely to impede timely completion of the Rim Country EIS and a Record of Decision.

Sincerely,

Jason Whiting, 4FRI co-chair

Jason Whiting
4FRI Stakeholder Group Co-chair

Travis Bruner, 4FRI co-chair

Travis Bruner
4FRI Stakeholder Group Co-chair

CC: Regional Forester Cal Joiner
Apache/Sitgreaves NF Supervisor Steve Best
Tonto NF Supervisor Neil Bosworth
Coconino NF Supervisor Laura Jo West
Kaibab NF Supervisor Heather Provencio

ITEM G:

Regional Forester Cal Joyner's Response to 1st 4FRI Objection

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**File Code:** 1570; 5150
**Date:** April 10, 2015

**Certified Mail:** 7008 0150 0000 9794 8075

Mr. Jay Lininger
Center for Biological Diversity
PO Box 710
Tucson, AZ 85702

Dear Mr. Lininger:

This letter is in response to the objections filed on the Four Forest Restoration Initiative (4FRI) Final Environmental Impact Statement (FEIS) and Draft Record of Decision (DROD) released by the Forest Supervisors of the Coconino and Kaibab National Forests, Earl Stewart and Mike Williams, respectively. I have read the objections and reviewed the project record and FEIS. My review of the objections was conducted in accordance with the administrative review procedures found at 36 CFR 218, Subparts A and B.

## OVERVIEW OF THE FOUR FOREST RESTORATION INITIATIVE

The Four Forest Restoration Initiative (4FRI) is a collaborative effort with over 30 stakeholder groups and the Forest Supervisors and staff of the Coconino, Kaibab, Tonto, and Apache-Sitgreaves National Forests. The 4FRI landscape spans 2.4 million acres across the Mogollon Rim of Northern Arizona and is the largest landscape-scale restoration project selected by the Collaborative Forest Landscape Restoration Program (CFLRP, established under section 4003(a) of Title IV of the Omnibus Public Land Management Act of 2009).

The FEIS documents the analysis of environmental effects associated with a suite of restoration treatments on approximately 586,110 acres of National Forest System lands. The project would be implemented over a 10-year period or until objectives are met. The area affected by the proposed decision includes approximately 355,707 acres on the Flagstaff, Mogollon, and Red Rock Ranger Districts of the Coconino National Forest and approximately 230,402 acres on the Williams and Tusayan Ranger Districts of the Kaibab National Forest.

## ADMINISTRATIVE REVIEW PROCESS

The legal notice of the objection filing period was published on December 5, 2014. Objections were received from the following eligible groups and individuals:

| | |
|---|---|
| • Marsha Honn | #15-03-00-0005-O218 |
| • Chad Hanson, John Muir Project | #15-03-00-0007-O218 |
| • Arthur Firstenberg | #15-03-00-0008-O218 |
| • Sandy Bahr, Sierra Club-Grand Canyon Chapter | #15-03-00-0009-O218 |
| • Stephen Dewhurst | #15-03-00-0010-O218 |
| • Jay Lininger, Center for Biological Diversity | #15-03-00-0011-O218 |
| • Kevin Mueller, WildEarth Guardians | #15-03-00-0012-O218 |
| • Dorothy Holasek | #15-03-00-0013-O218 |

An objection was also filed by William Baker (#15-03-00-0006-O218); however, his objection was set aside from review because he did not submit any comments during a designated opportunity to comment as required by the regulation at 36 CFR 218.5.

On February 10, 2015, I notified the eligible objectors that I was exercising my discretion under 36 CFR 218.26(b) to extend the time for the objection review until April 6, 2015. On April 3, 2015, I sent a letter to all objectors explaining my decision to further delay my response to the objections so that we could continue our discussions and attempt to resolve issues during the week of April 6. This extra time allowed us to continue our thorough review of the issues and meetings with objectors to attempt to resolve the issues. Over the last few weeks of March and the first two weeks of April, the Forest Supervisors and I met with several objectors to explore opportunities to resolve all or part of their objections. Meetings were held in person, via teleconference, and by video conference as follows:

- On March 16 we met with Chad Hanson (in person), John Muir Project (JMP); and Kevin Mueller (phone) and Bryan Bird (in person), WildEarth Guardians at the Southwestern Regional Office in Albuquerque. Dr. William Baker also attended, not in an objector capacity but rather as a science advisor to JMP and WildEarth Guardians.

- On March 18 we met with Todd Schulke (in person), Center for Biological Diversity; Sandy Bahr (phone) and Alicyn Gitlin (in person), Sierra Club; Stephen Dewhurst (in person), and Dorothy Holasek (phone) at the Coconino Forest Supervisor's Office in Flagstaff.

- Marsha Honn and Arthur Firstenberg declined to meet to discuss their objections.

Members of the 4FRI Stakeholders Group, the 4FRI Interdisciplinary Team, the general public, and other Forest Service resource specialists and staff also attended the meetings. Several follow up conference calls were held to continue discussions around resolution of the issues (March 25 and 27, April 1, 2, 6, 8 and 9). I appreciate the extraordinary amount of time and effort invested by all parties. The open, candid discussions allowed us to focus on those areas where we may be able to come to some resolution on the issues raised in the objections.

As a result of our continued dialogue, we were able to reach an agreement with WildEarth Guardians to resolve their issues. On April 10, 2015, an Objection Resolution Agreement documenting specific clarifications and modifications to be made to project documentation was signed by Kevin Mueller of WildEarth Guardians and the Responsible Officials (Forest Supervisors). The resolution included an agreement by WildEarth Guardians to withdraw their objection in whole. Upon the withdrawal of their objection, I issued a letter on April 10, 2015, setting aside their objection from further review in accordance with 36 CFR 218(a)(6).

While resolution was ultimately not reached with the other objectors, the meetings were productive and I believe that the proposals we discussed brought us closer to agreement. The Forest Supervisors have agreed to make the changes described below in order to demonstrate their commitment towards resolving the issues, even though, with the exception of WildEarth Guardians, the objectors chose not to withdraw their objections.

## RESPONSE TO ISSUES

I must provide a written response to the objections that sets forth reasons for the response; however, this response need not be point by point [36 CFR 218.11(b) and 36 CFR 218.57(b)]. The Responsible Officials and I have reviewed the project in light of the issues presented in your objection letters and during the course of the objection resolution meetings. While my response to each objector is not on a point-by-point basis, I want to assure you that we considered and reviewed all the issues and suggested remedies for all objections received. The modifications and clarifications we agreed to make to the FEIS and supporting documents as a result of the objection resolution meetings are described below. By copy of this letter, I am instructing the Forest Supervisors to document these modifications and clarifications to the FEIS and supporting documents in an appendix to the Record of Decision. None of the modifications and clarifications are substantial changes to the analysis for the decision nor do they present significant new circumstances or new information relevant to environmental concerns or bearing on the alternatives or impacts; therefore, a supplemental EIS is not required.

### Marsha Honn (0005) and Dorothy Holasek (0013)

Both Ms. Honn's and Ms. Holasek's objections were concerned with air quality and the public health effects of prescribed burning. Their concerns were adequately responded to in the response to comments on the Draft EIS. The FEIS appropriately discusses the release of contaminants from prescribed burns and complied with law, regulation, and policy in consideration of a range of alternatives for review. No further action by the Responsible Officials is required.

### Chad Hanson, John Muir Project (0007)

The objection filed by the John Muir Project (JMP) raised issues identical to those raised by WildEarth Guardians. The two groups presented a united front at the objection resolution meetings up until April 3, 2015, when JMP withdrew from the resolution process. JMP's objection raised the following issues:

11. Key scientific sources regarding historical forest structure and fire regimes, and Mexican spotted owl responses to fire are missing from the record.
12. Concerns regarding heterogeneity across the landscape.

JMP Issue 1: In the resolution agreement with WildEarth Guardians, the Forest Supervisors agreed to address the concern that findings of key scientific sources regarding historical forest structure and fire regimes, and Mexican spotted owl responses to fire are currently missing from the record, by modifying (in **bold**) the FEIS, Silviculture Report, and Fire Report as follows:

- Add language and references to the Silviculture Report outlining the forest density structure of Williams and Baker, et.al.

  **The forest structure described in various literature (Reynolds, et, al., 2013; Williams and Baker, 2012; William and Baker 2013; Woolsey, 1911; Pearson. 1950; Covington and Moore, 1994; Swetnam and Baisan, 1996; Covington, et. al., 1997) is very similar to that described in this project. While the individual metrics used in the literature to describe the desired stand structure vary slightly, it is clear that almost all of the stand densities in the 4FRI EIS fall within the Natural Range of Variability described in the relevant literature.**

- Compare the forest structure indicated in the literature to what is being proposed by the 1st 4FRI EIS (the forest densities are very similar).

| Literature-indicated Forest Structure | What the Silviculture Report/FEIS Propose (language can be added where needed) |
|---|---|
| Defined small trees as > 10cm up to 40 cm (3.9" up to 15.7" DBH).<br><br>Defines high density forests with approximately 141-145 trees/ha (57-59 trees per acre), and 17.3% of the forest exceeded 200 trees per hectare (81 Trees per acre), and 4.2% of the area exceeding 300 trees per acre (122 trees per acre).<br><br>58 TPA over 4" DBH<br>16-18% of forest areas >81 TPA<br>52-81% of trees under 16": DBH | **In Alternative C, 4FRI proposes mechanical treatment on 431,049 acres.**<br><br>**Post-treatment structure is:**<br>**VSS 2 (4.0-4.9") = 18.24 TPA (0-604) (28.1%)**<br>**VSS 3 (5.0-11.9") = 24.39 TPA (0-639) (37.5%)**<br>**VSS 4 (12.0-17.9") =12.7 TPA (0-84) (19.5%)**<br>**VSS 5 (18-23.9" = 6.89 TPA (0-53) (10.6%)**<br>**VSS 6 (24"+) = 2.83 TPA (0-18) (4.3%)**<br><br>**Total Trees Per Acre = 65.05**<br><br>**Projections for post-treatment density figures are:[6]**<br>**65.05 TPA across the treatment stands (4.0"+ DBH)**<br>**29.3% of stands are > 81TPA**<br>**90.3% of the stands have >52% of the trees** |

[6]Refer to Project Record #954, Summary of Projected Post-Treatment conditions by Type.

| | |
|---|---|
| | **<16" DBH.**<br><br>**The range of TPA is approximately 0-639 TPA** |

- Add language and reference to Fire Ecology Report (Introduction, p. 1, 5th paragraph)**:** **Landscape scale analyses are important for understanding how ecosystems responded historically to climate change or disturbances across environmental gradients (White and Jentsch, 2001).** Fire is a keystone process in healthy ponderosa pine ecosystems as well as grasslands, aspen, and other ecosystems within the analysis area. Fire Ecology is the study of the symbiotic relationship of fire with all spatial and temporal components of an ecosystem…

- In both the Fire Ecology Report and the Fire Ecology section of the FEIS, change "Opposing Science" heading to "**Other Science Reviewed**" and modify language in this section:

  Commenters also cited publications (Williams and Baker, 2013; Williams and Baker 2012) to support their comments. **Over the last several years, there has been a series of publications with differing conclusions about the role of fire in ponderosa pine forests in Arizona.** Williams and Baker compiled a large set of historical data that consists of records made by land surveyors for the General Land Office (GLO) in the late 1800s and early 1900s. Surveyors marked trees around corner points that delineated square miles and quarter-miles, sometimes making additional comments about the country they were walking through. This research provided new data in the form of estimates of forest density, species, and diameters of trees at the time of the survey **(Williams and Baker, 2012). Based on the density and size-class data, they devised a method for determining past fire regimes, concluding that the proportion of high-severity fire in recent fires was less than or similar to the proportion in historical fires (Williams and Baker 2012).** They also concluded that, **historically,** high severity fire was more prevalent across the ponderosa pine in Arizona than had been indicated by previous research **(cited elsewhere in this report). Fulé et. al. (2013) responded with concerns about Williams and Baker's (2012) methods and conclusions about high severity fire.**

  **In evaluating the available research that is specific to fire regimes in ponderosa pine in Arizona and the project area, many people feel that ecological, social, and economic values are not consistent with the pre-restoration disturbance regime of large, high severity fires, especially under changing climate. However, ecological restoration in the project area will lead to a restored fire regime with historical levels of low, mixed, and high-severity fire, even if the details of the historical levels remain under on-going study.**

- Add paragraph and modify language in Affected Environment, Historic conditions affecting the 4FRI analysis, section:

**The 4FRI project area lies between Grand Canyon National Park's South Rim and the southern boundary of the Coconino National Forest. This area is dominated by ponderosa pine that is intermixed with pinyon pine, juniper, Gambel oak, aspen, grassland, and shrubland vegetation. Across the landscape, this mosaic of vegetation supported, and was supported by, a mosaic of fire regimes, ranging from low to high severity (Williams and Baker 2013). The driest part of the project area is on the Coconino Plateau, where ponderosa pine forests may have been less continuous, with significant portions of the landscape being pinyon/juniper or grass and shrubs, and more of the ponderosa pine is intermixed with shrubs (such as sage), or pinyon/juniper. Studies done in this area showed that, particularly where pinyon/juniper and mixed conifer intermixed with ponderosa pine, low-severity fire likely structured the majority of the forest while roughly a third was structured by mixed-severity fire, probably including small, patchy crown fires (Williams and Baker 2013; Huffman et. al., 2008).**

Historically, both lightning and human-caused fires, once started, could burn until extinguished by rain, or until they ran out of fuel (typically when they reached an area that had recently burned). Fires could burn for months and cover thousands of acres (Swetnam 1990, Swetnam and Baisan 1996). Effects from these long burning fires would vary as conditions changed over the weeks they burned. As a result, most ponderosa pine in the southwest burned every 2 to 22 years as **mostly** low-severity, often area-wide fires (Weaver 1951, Cooper 1960, Dieterich 1980, Swetnam et al. 1990, Swetnam 1990, Swetnam and Baison 1996, Fulé et al. 1997a, Fulé et al. 2003, Covington et al. 1997, Heinlein et al. 2005).

Across the treatment area, the desired condition would allow the use of prescribed fires to supplement unplanned ignitions, producing an average annual Fire Return Interval (FRI) in the ponderosa pine of no more than 20 years, with a 10 year FRI being preferred unless monitoring indicates a change is warranted. The FRI on the southern end of the project would average less than 10 years because the higher precipitation produces faster regeneration and growth (Puhlick et al. 2012), while the northern, drier portion of the project area could go for 20 – 30 years, depending on environmental conditions affecting fuel accumulations, regeneration, and initial condition (Fulé and Laughlin 2007). Across the treatment area, forest conditions would allow for the use of fire as addressed in the land and resource management plan. Frequent surface fires would rarely move up into tree crowns and, when crown fire did occur, it would **mostly** be passive crown fire, limited to the tree or the group within which it started, **or small patchy areas of crown fire**. Restored sustainable fire regimes, from a combination of planned and unplanned ignitions, would regulate landscape structure, pattern, and composition, aligning forest changes with climate changes.

**While researchers generally agree that there was mixed and/or high severity fire in ponderosa pine (Williams and Baker 2013, Roccaforte et al. 2008), there are some unresolved questions about the amount, pattern, and distribution of these fires. Some studies on the rates of these fires suggest they were relatively infrequent (Williams and Baker 2012). This is corroborated by Jenkins et al. (2011), whose paleoecological reconstruction found high-severity fires in transitional ponderosa and dry mixed-conifer forests at 200-600 year intervals over the last 1000 years.**

Some science indicates the size and extent of high severity fires are much larger than historic data indicates was typical of ponderosa pine in the southwest (Swetnam 1990, Covington and Moore 1994; Swetnam and Betancourt 1998, Westerling et al. 2006, Climate Central 2012, Miller and Safford 2012) and, while the number of fires reported in and adjacent to the project area has decreased over the last 40 years, the average size has increased.

These modifications and clarifications also respond to JMP's concerns and no further action by the Forest Supervisors is required with respect to this issue.

<u>JMP Issue 2:</u> In the resolution agreement with WildEarth Guardians, the Forest Supervisors agreed to address the concerns regarding heterogeneity across the landscape, by modifying (in **bold**) the ROD, FEIS, Silviculture Report and Fire Report as follows:

- Add the following language to promote heterogeneity to the Final ROD:

  **The objective of the project is to restore forest structure, pattern, composition, diversity and landscape heterogeneity, within the ponderosa pine (Pinus ponderosa) ecosystem that will lead to increased forest resiliency and function and restore the historical fire regime. The intent of the 4FRI project is to obtain a high level of vegetative responses that will increase ecosystem diversity by increasing horizontal and vertical heterogeneity. Restoration initiates or accelerates ecosystem recovery with respect to ecological health, integrity, and sustainability (Reynolds et al 2013). Resiliency increases the ability of the ponderosa pine forest to survive natural disturbances such as insects, diseases, fire, and climate change (FSM 2020.5) without changing its inherent function (SER 2004). Restoration activities proposed with this project are expected to put the project area on a trajectory towards comprehensive, landscape-scale restoration, with benefits that include improved vegetation biodiversity, wildlife habitat, soil productivity, and watershed function, as well as increased forest structure heterogeneity. To ensure that the project will maintain and restore historical forest structure, the restored landscapes of the project area are projected to have an average of at least 65 trees/acre over 4" diameter, 29% of forest area with > 81 trees/acre, and 90% of forest stands with > 52% of the trees < 16" diameter as documented by scientific reconstructions of historical forest structure.**

**Restoration treatments will expand burn windows for both planned and unplanned ignitions, so that the proportion of the project area with restored historical levels of low, mixed, and high-severity fires is maximized. While the 4FRI does not provide any direction for managing unplanned ignitions, treatments are expected to increase the decision space for line officers deciding how to manage lightning caused fires wildfires. This can be expected to increase the area that can be managed for historic fire regimes, including low, mixed, and high severity fire.**

- This language in the Final ROD will be supported in the FEIS, Silviculture Report, and Fire Report by adding the following language to those documents:
    - **Alternative C includes mechanical treatments on 431,049 acres.**
    - **The post-treatment tree density (trees per acre, TPA), after mechanical treatments and prescribed fires, across the 431,049 acres, is projected to be no less than 65 TPA (mean).**
    - **In the post-treatment landscape, across the 431,049 acres, it is projected that more than 16% of stands will have no less than 81 TPA (mean).**
    - **The post-treatment landscape, across the 431,049 acres, is projected to be dominated by small trees, with more than 51.8% of the trees smaller than 15.7" DBH.**
- Discussion and explanation of other scientific references, published prior to the completion of the 4FRI EIS analysis, will be added or expanded upon in the FEIS, Silviculture Report, and Fire Report for the following literature and findings:
    - **Williams and Baker (2013) found the mean density of historical forests was 142-144 trees/ha (57-59 TPA), and 16-18% of forest area was dense, with > 200 trees/ha (81 TPA).**
    - **Leiberg et al. (1904): "The light stands in many cases represent tracts which were burned clear, or nearly so, one hundred or one hundred and twenty years ago, and now are stocked chiefly with sapling growths, ranging in age from 35 to 90 years."**
    - **Jenkins et al. (2011 p. 138-139): "…the evidence indicates that severe wildfire was an important influence on the pre-European-settlement landscape in transitional PIPO and PIPO-MC…Fires are recorded in our study area with a frequency of several centuries, ranging from 600 to 200 years for multiple-basin events."**

- **Williams and Baker (2012): This study found that the historical fire regime in ponderosa pine forests on the Mogollon Plateau included 62.4% of the area with evidence of only low-severity fire, 23.1% of the area with mixed-severity fire, and 14.5% of the area with high-severity fire (Williams and Baker 2012, Table 2). Also, the historical fire rotation for high-severity fire was 828 years across the Mogollon Plateau, thus these fires were infrequent, as also found by Jenkins et al.**

- **Williams and Baker (2013): This study found that the historical fire regime in ponderosa pine forests on the Coconino Plateau included 58.8% of the area with evidence of only low-severity fire, 38.7% of area with mixed-severity fire, and 2.5% of area with high-severity fire (Williams and Baker 2013, Table 2).**

These modifications and clarifications also respond to JMP's concerns and no further action by the Forest Supervisors is required with respect to this issue.

**Arthur Firstenberg (0008)**

Mr. Firstenberg's objection alleged the agency failed to adequately address effects of the project on people with disabilities and failed to analyze the effects of escaped prescribed burns. These issues were adequately responded to in the response to comments on the Draft EIS and specifically addressed in the FEIS.

Mr. Firstenberg also raised several issues related to opposing science. Although he had not raised these issues previously as required by 36 CFR 218.10, the we reviewed the issues and determined they had been sufficiently dealt with in the analysis and/or decision rationale. No further action by the Forest Supervisors is required.

**Sandy Bahr, Sierra Club; also represented by Alicyn Gitlin (0009)**

Sierra Club's objection raised the following issues:

16. The agency failed to disclose the cumulative effects of 4FRI project implementation combined with permitted grazing.
17. The agency failed to disclose all factors contributing to aspen decline in the project landscape and failed to consider best available science.
18. Neither the proposed project nor the Biological Opinion establishes a monitoring plan or requirements to assess the effects of the project on Mexican spotted owl (MSO).

In order to address the issues related to cumulative effects and aspen decline, the Sierra Club proposed several modifications and clarifications that could be made to resolve their issues. Based on their review of these suggestions, the Forest Supervisors have agreed to provide further discussion and clarification as follows:

Sierra Club Issue 1: Link tree density to historic grazing and associated removal of understory (mention is made of reduced grasses and forbs; but link not made to increased tree density, inability to carry fire, or reduced competition of seedlings with understory plants).

- Modify Appendix F (Cumulative Effects) to include a discussion on how historic grazing influenced the existing condition. Add references such as Drake (1910), Belsky and Blumenthal (1997) and Bakker et al. (2010) to this discussion.

Sierra Club Issue 2: Mention interaction of grazing with fire suppression to degrade forests, including old growth forests.

- Add grazing presence/absence and grazing intensity as indicators to the Monitoring Plan (Appendix E). Add grazing as a monitored covariable of the existing indicators in Appendix E (Monitoring Plan). Add range readiness language to Appendix C (Design Features, Best Management Practices, and Mitigation) and Appendix D (Implementation Plan).

Sierra Club Issue 3: Noxious weeds/cheatgrass; mention reduced competitive and reproductive capacities of native species in grazed areas, and that actions associated with grazing can spread exotic plant seed.

- Add the Belsky and Blumenthal (1997) reference to the discussion on the historical impact of livestock grazing to grasslands in Appendix F (Cumulative Effects).

Sierra Club Issue 4: Grazing contributes to aspen decline/detrimental to aspen recruitment and survival.

- Modify the design features in Appendix C (Design Features, Best Management Practices, and Mitigation) to include measures that would be taken to protect aspen.

- Modify the Fire effects analysis to include language on deterrents used to protect aspen from ungulate grazing.

- Add to the Purpose and Need section of the FEIS and Appendix F (Cumulative Effects) citations from Ripple and Beschta 2007, 2011 and Hebblewhite et al., 2005.

- Incorporate language from the Range Report specific to grazing and impacts to aspen into the Water Quality and Riparian Analysis section of Chapter 3 of the FEIS and Appendix F (Cumulative Effects).

Sierra Club Issue 5: Grazing impacts springs/riparian areas; interaction with OHV use.

- Incorporate language from the Range Report specific to grazing and impacts to aspen into the Water Quality and Riparian Analysis section of Chapter 3 of the FEIS and Appendix F (Cumulative Effects).

<u>Sierra Club Issue 6:</u> Add the following references to peer-reviewed literature: Kerns et al. 2011 (which describes USDA research: "understory release from a long history of cattle grazing caused a greater degree of change than the initial reintroduction of fire."), Belsky and Blumenthal 1997, Cooper 1960, Madany and West 1983, Savage and Swetnam 1990, Arnold 1950.

- Add a discussion on how historic grazing influenced existing condition to Appendix F (Cumulative Effects). Add Belsky and Blumenthal 1997, Cooper 1960, Madany and West 1983, Savage and Swetnam 1990, Arnold 1950 references to this discussion.

<u>Sierra Club Issue 7:</u> Explain how future livestock management would differ from the past practices that helped lead to unhealthy forests in the first place.

- Clarify how range readiness is assessed in the Range Report and clearly link range readiness to the Implementation Plan (Appendix D) and the Monitoring Plan (Appendix E).

- Add range readiness to the project design features (Appendix C).

- Clarify in the range report that allotment management monitoring occurs in addition to 4FRI monitoring.

- Add language to the cumulative effects discussion in Appendix F that directs readers to the Range Report for information on grazing program-related requirements that set the sideboards on utilization, pasture use, etc.

<u>Sierra Club Issue 8:</u> Explain how monitoring will detect problems and what changes might be made to grazing practices in the future, including changes to timing, duration, stocking rates, or availability of pastures.

- Add language to the ROD that describes the complexity of grazing activity occurring concurrently with restoration treatments. Clarify that the allotment management plan (AMP) and annual operating instructions (AOI) process is the mechanism used to decrease or increase grazing numbers (not site-specific projects). Explain that monitoring for 4FRI will help inform future grazing analyses.

<u>Sierra Club Issue 9:</u> Acknowledge that removal of livestock after treatment (fire, cutting, or seeding/planting/mulching) may be necessary for a period of years. Only fire is mentioned as potentially impacting the availability of pastures to livestock, but if forests are returning to an unhealthy state (i.e., reduced understory, dense regeneration, altered fire regimes, noxious weeds) then livestock utilization may have to be altered.

- Modify the Range section in Chapter 3 of the FEIS to include vegetation treatments as a ground-disturbing action that will be considered along with fire.

- Clarify in Appendix C (Design Features, Best Management Practices, and Mitigation) and range report that restrictions in grazing of livestock will occur after significant burns in pastures, that livestock pasture rest after ground disturbing treatments (i.e., thinning, seeding, and aspen restoration) may occur, and that line officers will evaluate, at a minimum, annual monitoring of range readiness to determine when grazing may resume within a pasture.

- Clarify in Appendix C and range report that annual monitoring includes measures for forage production, precipitation, forage utilization, livestock numbers, and livestock season of use.

- Clarify in Appendix C and range report that condition and trend monitoring every five to 10 years measures plant canopy cover, plant frequency, and ground cover.

- Modify a design feature in Appendix C (Design Features, Best Management Practices, and Mitigation) to clarify the process of evaluating range readiness after ground-disturbing treatments.

With respect to the Sierra Club's issue related to the MSO monitoring plan, please see the responses to the Center for Biological Diversity objection below.

**Stephen Dewhurst (0010)**

Mr. Dewhurst's objection raised the following issues:

11. The FEIS failed to develop and analyze a full ecological restoration alternative, resulting in an inadequate range of alternatives.

12. The FEIS revised the purpose and need after the analysis was complete by changing the desired conditions in the Fire Regime Condition Class (FRCC) section of the purpose and need.

To demonstrate how the purpose and need changed, Mr. Dewhurst pointed out the differences in Table 13 between the draft and final EIS. Upon review of the table, the Forest Supervisors understand why it gives the impression that the desired conditions were changed. They have agreed to provide further clarification and discussion as follows:

- Correct the FRCC table, modify the table description and add a statement in this section to define FRCC and clarify that FRCC 1 is within the historic range and 2 and 3 are departed.

Table 13. Existing and Desired Conditions for Vegetation Condition Classes/Fire Regime Condition Classes in Ponderosa Pine

| | Existing Condition (% of total area) | Desired Condition (% of total area) |
|---|---|---|
| Vegetation Condition Class 1 | 14 | 85 – 95 |
| Vegetation Condition Class 2 | 25 | 5 – 15 |
| Vegetation Condition Class 3 | 61 | 0 |
| **Fire Regime Condition Class of Treatment Area** | **3*** | **1*** |

*Habitat requirements for MSO and goshawk in the ponderosa pine type will limit the intensity of vegetation treatments in some areas. The number of acres this applies to may vary over the life of this project.

Add the following statement:

> **The desired condition is to have a range of 85 to 95 percent of the ponderosa pine in vegetation condition class 1 (see table 13). There would be a range of 5 to 15 percent vegetation condition class 2. There would be zero percent in the vegetation condition class 3. The desired condition for the ponderosa pine is FRCC 1; however, habitat requirements for MSO and goshawk in the ponderosa pine will limit the intensity of vegetation treatments in some areas. The number of acres this applies to may vary over the life of this project.**
>
> **Fire regime condition class assessments determine how departed a landscape's fire regime is from its historic fire regime. It is scaled from 1 to 3, with 3 being the most departed and 1 being the least departed. The fire regime is significantly departed from historical ranges on about 66 percent of the project area. The project area is classified as FRCC 3 (table 13). In FRCC 3, the risk of losing key ecosystem components is high. Approximately 25 percent of the project area is in FRCC 2, indicating the ecosystem is moderately departed from its historical range.**

With respect to the contention that the FEIS failed to analyze an adequate range of alternatives because it failed to consider a full restoration alternative in detail, the range of alternatives considered by the Responsible Officials included five alternatives analyzed in detail, and six alternatives, including an evidence-based full restoration alternative, were considered but eliminated from detailed study. The record adequately describes the rationale for eliminating alternatives from detailed study. The Forest Supervisors have agreed to send Mr. Dewhurst the full restoration alternative evaluation paper which includes rationale for eliminating the alternative from detailed analysis for his review. No further action by the Forest Supervisors is required.

**Jay Lininger, Center for Biological Diversity (CBD); represented by Todd Schulke (0011)**

The Center for Biological Diversity's objection raised issues related to canopy cover, goshawk survey requirements, and treatments and monitoring in Mexican spotted owl Protected Activity Centers (PACs).

In order to address the specific concerns related to these issues, CBD proposed several modifications and clarifications that could be made that would resolve their issues. Based on their review of these suggestions, the Forest Supervisors have agreed to provide further discussion and clarification as follows:

CBD Issue 1: The FEIS uses the word "intent" throughout the implementation plan in relation to retaining canopy cover at the existing forest plan standard level in "high" VSS, and VSS 5 and 6 stands. The FEIS needs to be unequivocal in following the existing standards and guidelines.

- Modify Appendix D (implementation plan) to change the language from "intend to" to "will" on 38,260 acres. This modification will also be made in the ROD.

CBD Issue 2: The FEIS is only clear about using the landscape canopy standard from existing (Coconino) and previous (Kaibab) forest plans in stands that were slated for higher intensity treatments. The assumption was that the upper 4's, 5's and 6's that were under lighter prescriptions would not go below the plan canopy cover standards. But the way the ROD and the FEIS are written there isn't explicit guidance for this nor is there any clear mechanism for monitoring this.

- Add language to the implementation plan (Appendix D), FEIS, silviculture report and ROD that includes less intensive treatments on about 46,090 total acres where there is a preponderance of large trees (upper VSS 4, 5, 6). This will add about 7,835 acres to the 38,260 acres that were included in the FEIS and draft ROD. The language for these additional acres will be modified in Appendix D (Implementation plan) as described in the Issue1 response. Modified language will state that, on approximately 46,090 acres, both ground-based and remote sensing monitoring will occur to document and ensure sufficient canopy cover remains (in the identified stands with a preponderance of large trees), and to compare the two methods.

- Modify existing language in the ROD to note that approximately 46,090 acres (total) will be treated less intensively. Assure Appendix D (implementation plan) and the ROD are consistent.

- It was noted that the monitoring plan already provides various methods for monitoring, including remote sensing and field (ground-based) validation. No change is needed to the monitoring plan.

CBD Issue 3: Adopt design features and/or Implementation Plan components to ensure that vertical crown projection is measured using ground-based methods throughout the project area.

- Add language to the Decision Rationale section of the ROD to explain that there is unresolved conflict related to measuring canopy cover.
- Clarify in the Implementation Plan (Appendix D), FEIS, Silviculture Report and ROD that canopy cover measurements on an additional 7,835 acres where there is a preponderance of large trees (for a total 46,090 total acres) will use both ground-based and remote sensing methods to ensure and compare consistency with expected canopy cover levels.
- Clarify in the ROD that both CBD and the Forest Service considered resolution of this issue larger than 4FRI, requiring involvement from multiple resources, including research. The Multi-Party Monitoring board will facilitate the process and develop a way to compare methods.

CBD Issue 4: Include in Amendment 2 up to 2,500 acres recommended by the Arizona Game and Fish Department ("AGFD") as corridors for grassland wildlife (Rosenstock and Gist 2014). Apply conservation measures for old growth and large trees within grassland corridors, such as a diameter cap. We request an addition to wildlife corridor deferral from forest plan canopy cover retention.

- Modify the ROD and Appendix D (Implementation Plan) to address the inclusion of approximately 2,750 acres of wildlife corridor explaining that "VSS 5 and 6 tree groups will be retained within the 2,750 acres designated for corridor treatments outlined in Rosenstock and Gist (2014)."
- Modify the Implementation Plan (Appendix D) to add: The wildlife corridor will be designed in alignment with the Large and Old Tree Implementation Plans. If there is potential for the corridor to affect VSS 5 and 6, adjustments (avoidance) will be made.
- Modify the Forest Plan Amendment 2 section of Appendix B (FEIS Forest Plan Amendments) to explain that the Coconino NF portion of the corridor will be deferred from forest plan canopy cover retention.

CBD Issue 5: Monitoring of Mexican spotted owl.

To resolve CBD's issues around monitoring and implementation of combined (mechanical/fire) treatments in Mexican spotted owl (MSO) Protected Activity Centers (PACs), the Forest Supervisors agree to make the following changes (in **bold**) to the MSO Monitoring Plan (FEIS, Appendix E):

- **Four** PACs will initially be selected from the pool of 18 for combined treatment, and at **least 4 reference PACs** will be selected for comparison.

- **Treatment of the remaining 14 PACs will be contingent upon the results of monitoring during this initial phase of PAC treatments.**

- **Of the 18 candidate PACs, those dominated by stands proposed for 9 inch dbh cutting limits will be prioritized for treatment and monitoring, provided that they are currently occupied.**

- **In the 18 combined treatment PACs, trees up to 17.9 inches dbh may be cut; however, trees over 14 inches dbh will not be removed. These select trees between 14-17.9 dbh may be felled and left onsite as logs, converted into snags, or burned. Coarse woody debris / surface fuels in treated PACs will be retained at levels compliant with forest plans.**

- **Pending U.S. Fish and Wildlife Service (FWS) approval and to the extent possible, all MSO residing in treated and reference PACs will be banded with unique color-coded leg bands to allow for individual identification and monitoring before, during, and after treatments have been implemented.**

- Surveys for occupancy and reproductive success will be conducted for two seasons before any PACs where MSO are detected receive combined treatments.

- **In the event that any of the 18 aforementioned PACs are surveyed for MSO occupancy for 3 consecutive seasons and no MSO are detected, treatment within those PACs may commence to retain and improve MSO habitat components (in addition to the 4 PACs discussed above). Monitoring within these PACs will remain consistent with occupied PACs.**

- Surveys for occupancy and reproductive success will be conducted in consecutive years post-treatment starting with the year of mechanical treatment and continuing until two years post-prescribed fire treatments.

- Vegetation data will be collected prior to treatment, then one year post-mechanical treatment and two years post-fire treatment for a total of three visits per PAC.

- Vegetation and spotted owl survey protocols will remain consistent across treatment groups and throughout the monitoring period.

- **If any of the 18 PACs being monitored burn at mixed or high severity, the monitoring will continue for 3 consecutive seasons.**

- **In the event that a mixed- or high-severity fire burns in any of the 117 PACs within the analysis area, MSO monitoring will be initiated and will continue for at least three consecutive years in all burned PACs. However, no more than 6 PACs affected in this way will be monitored during any given year. If monitoring objectives other than post-fire occupancy are included in this monitoring plan then there will be reductions in sample size to offset increasing expense per PAC. If the number of PACs burned as described exceeds the number to be monitored then there will be a preference to continue monitoring PACs for which baseline (pre-burn) data exist.**

- **A summary of the data collected during PAC monitoring will be made publically available and presented to the stakeholder group on an annual basis.**

- **The Multi-Party Monitoring Board will evaluate monitoring outcomes and other relevant science to develop and provide recommendations regarding future treatments in MSO PACs.**

- **Funds for the MSO monitoring will be established and demonstrated to the Multi-Party Monitoring Board prior to any treatments occurring in the 18 PACs.**

The following language will be added to the ROD and Attachment 1, MSO Project Monitoring, of the Monitoring Plan (Appendix E):

- There is mutual recognition of the need to evaluate the impacts of vegetation treatments on Mexican Spotted Owl (MSO) and its habitat at a broad scale. There is also a mutual understanding that the desired evaluation is beyond the scope of a single project such as the Four Forest Restoration Initiative. We have agreed to convene a working group that will design such a study. We anticipate that this effort will bring together subject matter experts, including representatives of the Forest Service, the U.S. Fish and Wildlife Service, the Rocky Mountain Research Station and other research stations, and the MSO Recovery Team, in cooperation with the Center for Biological Diversity and other stakeholders as appropriate.

- The primary objective of the first meeting will be to bring forward the key questions related to characterizing the effects of vegetation treatments on MSO and its habitat and to identify the resources needed to rigorously evaluate these effects at the appropriate scale. The group will review the best available science and develop a consistent monitoring approach across multiple administrative units, expanding upon existing monitoring efforts where appropriate.

CBD Issue 6: Concerns regarding requirements for northern goshawk surveys on both the Coconino and Kaibab National Forest.

- Add language in the ROD, Appendix C (Design Features, Best Management Practices, and Mitigation), Appendix E (Monitoring Plan), and the wildlife report to clarify that pre-treatment goshawk occupancy surveys will be conducted in goshawk habitat on both forests.

## CLOSING

I want to thank those of you who participated throughout this project development and administrative review process. Your input and participation have been extremely valuable in helping the agency make more informed decisions. I also want to thank the 4FRI Stakeholders Group and Coconino and Kaibab National Forest employees who have put so much effort into what has been a very complex project development, analysis, and planning effort. The stakeholders and forest employees' professionalism and dedication to this landscape-scale restoration initiative is greatly valued and appreciated by me, the agency, and the public we serve.

By copy of this letter, I instruct the Forest Supervisors to comply with my written response, as well as the changes they have agreed to make as outlined above. As soon as they have complied with the instructions, they may sign the final ROD and notify interested and affected publics of their decision.

My review constitutes the final administrative determination of the Department of Agriculture. No further review from any other Forest Service or USDA official of my written response to the objections is available [36 CFR 218.11(b)(2)].

Sincerely,

Calvin N. Joyner

CALVIN N. JOYNER
Regional Forester

cc: Earl Stewart, Scott Russell, Mike Williams

ITEM H.

4FRI Strategic Treatments for Fire Use Alternative
Prepared by the Center for the 4FRI Rim Country Analysis.

# THE STRATEGIC TREATMENTS FOR FIRE USE ALTERNATIVE

*Prepared by*

THE CENTER FOR BIOLOGICAL DIVERSITY

*For the benefit of*

THE FOUR FOREST RESTORATION INITIATIVE
STAKEHOLDERS AND THE U.S. FOREST SERVICE

MAY, 2018

## EXECUTIVE SUMMARY

The U.S. Forest Service (USFS) is currently preparing an Environmental Impact Statement (EIS) for 'Rim Country' - the 2nd phase of NEPA planning under Arizona's Four Forest Restoration Initiative ("4FRI"), the largest forest restoration project yet undertaken in the U.S. and a centerpiece of the Collaborative Forest Landscape Restoration Program (CFLRP). As a foundational member of the 4FRI collaborative, the Center for Biological Diversity ("The Center") shares a deep commitment to accomplishing landscape-scale forest restoration. However, the Center is increasingly concerned that Rim Country planning is headed in the wrong direction, putting the entire effort at risk. Specifically, we feel that Rim Country has deviated from core tenets of 4FRI and the zone of agreement between USFS and 4FRI stakeholders, is overly reliant on mechanical thinning to meet restoration objectives, does not adequately reflect current policy guidance, and fails to incorporate the best available science. To address these concerns, on March 13, 2018, The Center submitted a formal request for a new, stand-alone *Strategic Treatments for Fire Use Alternative* to the Regional Forester and 4FRI Board. This follow-up document presents detailed background, justification, and design parameters for the requested alternative.

The current restoration paradigm underlying Rim Country is seriously flawed. It retains allegiance to the regulated-forest model, which requires regular mechanical intervention to attain and maintain "desired conditions" of forest composition and structure - an approach that is clearly at odds with natural disturbance regimes in these forests, by emphasizing fixed structural attributes rather than those shaped by spatially and temporally dynamic natural processes. USFS has also proposed aggressive mechanical treatments aka "Extended Duration Restoration" (EDR), which have uncertain ecological impacts and unknown ability to meet restoration objectives. From an operational perspective, Rim Country assumes that mechanical thinning can be applied at scale in a timely fashion, which has thus far proven unattainable across much of the first 4FRI EIS area. That unfortunate situation is unlikely to improve, and may in fact worsen, if new industry cannot be successfully established and a succession of new projects produce large volumes of biomass and other low-value material having few outlets. Simply put, USFS is attempting to impose a simplistic and arguably non-viable silvicultural solution on a complex ecological problem that is becoming ever more acute.

Given these circumstances and uncertainties, The Center asserts that expanded use of prescribed and resource benefit fire, coupled with strategic placement of mechanical treatments, is the best means to accomplish implementation of Rim Country in an ecologically sound manner and within reasonable time frames. The Rim Country landscape is ideally positioned for this, with current management direction strongly supportive of enhanced fire use. The *Strategic Treatments for Fire Use Alternative* is a principled, attainable, science-based approach to protect values-at-risk from undesirable fire effects, while allowing natural process-structure interactions to drive ecosystem restoration and improve resiliency.

The *Strategic Treatments for Fire Use Alternative* builds upon an extensive body of work by USFS and academic scientists, providing a spatially-explicit means to prioritize the Rim Country landscape and identify optimal treatment actions. The strategy incorporates the probability of an area to support fire of low, mixed, or high-severity, values-at-risk, existing planning/prioritization, a consensus-based suite of treatments, and key elements of the current proposed action for Rim Country. Under the *Strategic Treatments for Fire Use Alternative*, the planning area would be stratified into three management area tiers which provide for *Community Protection*, *Strategic Thinning Treatment*, and *Fire Use*. *Community Protection* areas (Tier 1) would be defined by existing plans and buffers around values-at-risk and represent the highest priority for mechanical treatment. *Strategic Thinning Treatment* areas (Tier 2) represent the next priority level for mechanical treatment and would be defined through optimization analysis. The proposed "Flexible Toolbox Approach" (FTA) could be applied within Tier 2, with addition of a "fire-only" option where stand conditions permit. *Fire Use Management Areas* (Tier 3) include all areas not included in Tiers 1 and 2, and would be treated using prescribed or resource benefit fire. We present recommendations for defining these management zones, with the expectation that they would be further refined through the collaborative process.

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## I. 4FRI IS HEADED IN THE WRONG DIRECTION

The origin of the contemporary health crisis affecting Southwestern forests lies squarely on past attempts to bring order to wild, natural ecosystems. Fire suppression, old-growth liquidation, excessive livestock grazing, and application of silvicultural systems designed to maximize sawtimber production are primary factors that led to degraded forest health, diminished ecological integrity, and reduced resilience to climate change and other perturbations. Recognizing the need for comprehensive ecological restoration of degraded fire-adapted forests, watersheds, and endangered species habitats, a diverse group of stakeholders united in search of solutions, in what later became the Four Forest Restoration Initiative ("4FRI"). A seminal report by these stakeholders was the Statewide Strategy for Restoring Arizona's Forests ("Statewide Strategy"),[1] released in June 2007; two years before the Collaborative Forest Landscape Restoration Program (CFLRP) was authorized by Congress. Following passage of the CFLRP, stakeholders developed other foundational documents, including *The Path Forward* (March 2010), and the *Landscape Restoration Strategy for the First Analysis Area*[2] (October 2010), among other key collaborative products. These steps led to the 2011 Memorandum of Understanding (MOU[3]) between 4FRI stakeholders and the U.S. Forest Service (USFS), and ultimately to the Record of Decision that initiated implementation of the consensus-based plan analyzed in the first EIS (April 2015).

The Center believes that 4FRI planning is now moving in the wrong direction, with excessive emphasis on structural manipulation and insufficient attention to fire-driven ecological processes. In response, we have prepared the *Strategic Treatments for Fire Use Alternative* as a change of course to accomplish 4FRI's goals in a more effective and efficient manner. Fundamental to all guiding 4FRI documents is the need for strategically prioritizing and placing mechanical thinning treatments that facilitate safe application of prescribed and wildland fire. This need is consistent throughout the entire history of 4FRI. At the core of the *Strategic Treatments for Fire Use Alternative* is our position that the current direction in planning, analysis and implementation is overly reliant on meeting structural and compositional targets, representing what is in effect a non-viable silvicultural solution to a complex ecological problem. The quest to create the ideal vegetative state across every operable acre has marginalized the overriding importance of fire-driven ecological processes. Applying a new form of growth and density regulation, as articulated in GTR-310[4], cannot by itself accomplish restoration at meaningful landscape scale; only the additive effects of frequent fire can fully restore these ecosystems.

Strategically placed mechanical thinning has a critical role in Rim Country: to reduce the risk of uncharacteristic fire, and preparing for safe fire re-entry.[5] Currently, as much of the 4FRI landscape is densely stocked with dangerous surface fuel loads and ladder fuels, mechanical thinning is a viable tool

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[1] Governor's Forest Health Council, State of Arizona. June 2007. The Statewide Strategy for Restoring Arizona's Forests. Aumack, E., T. Sisk, and J. Palumbo, editors. Published by Arizona Public Service, Phoenix, AZ.

[2] Sesnie, S.E., J. Rundall, S. Hedwall, and V. Horncastle, technical editors. October 1, 2010. Landscape restoration strategy for the first analysis area: report from the Four Forests Restoration Initiative Stakeholder Group to the USFS Planning Team.

[3] Memorandum of Understanding between the 4 Forest Restoration Initiative (4FRI) Collaborative Stakeholder Group Representatives and the U.S. Forest Service, signed February 22, 2011.

[4] Reynolds *et al.* 2013. Restoring composition and structure in Southwestern frequent-fire forests: A science-based framework for improving ecosystem resiliency. RMRS-GTR-310.

[5] Stephens *et al.* 2016. U.S. federal fire and forest policy: emphasizing resilience in dry forests. *Ecosphere* 7(11): 1-19.

for preparing those areas for successful re-establishment of a predominantly low-intensity, frequent fire regime. However, if current implementation trends continue, that work cannot be accomplished at a pace commensurate with the scale of the ecological problem, and as such a course correction is needed. Because many acres identified for thinning may be poor candidates for economically-viable mechanical treatment but suitable for fire-based restoration, strategic placement of mechanical thinning is essential.

The 2011 MOU stated that "*The goal of landscape-scale restoration includes assessment of 2.4 million acres, identification of priority treatment areas, and aggressive implementation of restoration at an accelerated rate over the next 20-30 years.*" The four foundational underpinnings of this agreement (landscape assessment, NEPA analysis/planning, prioritization, and implementation) have not been fully realized. The first two elements have proven possible: the 4FRI collaborative and USFS successfully assessed and analyzed approximately half of the 4FRI landscape in the first EIS. However, the third and fourth elements have encountered significant challenges that call for an adaptive response:

1) The commitment to strategically place treatments was a foundational principle early in 4FRI's development; however, that direction was abandoned by USFS in favor of a new form of the regulated-forest model, albeit one that considers more than just timber production. The *Strategic Treatments for Fire Use* Alternative is centralized around advantages of returning to this strategic approach.

2) There was an expectation that issuing a landscape-scale, long term contract for harvest of wood fiber would facilitate expansion of industry needed to accomplish mechanical thinning objectives, particularly on the western portion of the 4FRI footprint. Unfortunately, this assumption has proven false, thanks to a series of missteps in contractor selection and their subsequent sub-standard performance.

These two facts, which are inextricably linked, support our call for strategic deployment of existing resources where they will yield the greatest restoration benefit. The degree to which 4FRI – the nation's largest CFLRP – does or does not achieve effective and timely ecological restoration will have effects beyond Arizona and the 4FRI National Forests; 4FRI has national significance and the potential to influence forest management nationwide. A successful outcome is crucially important, and as a founding Stakeholder and active party in every step in this process, the Center cannot let the current predicament go on without a return to the foundational principles and assumptions.

The Rim Country analysis will lead to a more effective outcome if it proceeds within existing consensus-based guidance developed from more than a decade of collaborative work. However, the extent of mechanical operations currently proposed under the USFS's proposed action (June 2016[6]) exceeds consensus-based determinations of the portion of 4FRI acres that should be mechanically thinned. The March 2010 document *The Path Forward* states that "*Landscape-scale restoration efforts should use elements of the consensus scenario developed in the Analysis of Small Diameter Wood Supply in Northern Arizona as sideboards for landscape scale restoration across the Four Forest Restoration area*," which includes the "*Percentage of landscape management areas to be mechanically thinned.*" The *Analysis of Small-Diameter Wood Supply in Northern Arizona* achieved consensus around mechanical thinning on appropriately 41% of the 2.4 million-acre 4FRI landscape[7]. In the first EIS, approximately 44% of the

[6] https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd506786.pdf

[7] Hampton *et al.* 2011. Estimating regional wood supply based on stakeholder consensus for forest restoration in northern Arizona. *Journal of Forestry* 109: 15-26.

analysis area was authorized for mechanical thinning – which equates to 72,000 acres beyond the consensus agreement – but because the Center is not unreasonable we did not object to this departure from the zone of agreement.

Now, the Rim Country proposed action makes up to 54% of the landscape available for mechanical thinning, approximately 161,000 acres beyond the consensus. Across both analyses, this departure equates to almost 192,000 acres. *The Strategic Treatments for Fire Use Alternative* provides a framework for reducing the total area projected for mechanical treatment to the zone of agreement shared by foundational 4FRI stakeholders. Additionally, this framework offers a pathway to return to 4FRI's original intent of prioritizing and strategically placing treatments, consistent with the most frequently cited principles for ecological restoration of southwestern ponderosa pine forests, which explicitly urge practitioners to "*Prioritize and strategically target treatment areas.*"[8]

**Aggressive Structural Treatments Are Unproven and Unjustified**

The USFS's current emphasis on aggressive structural manipulation to very low densities, as articulated in the Extended Duration Treatment (EDR) proposal for Rim Country, is an essentially unproven approach that lies outside the current zone of agreement among 4FRI stakeholders. As such, the EDR approach may be appropriate only in the Wildland Urban Interface, where infrastructure protection and fire suppression are primary management considerations. Treatments elsewhere on the Rim Country landscape should instead "*focus on creating conditions in which fire can occur without devastating consequences.*"[9] A 2013 Ecological Restoration Institute synopsis titled *Fuel Treatment Longevity*[10] identified 25 factors affecting fuel treatment longevity. Among those was "Treatment Intensity," which was only briefly mentioned as a bulleted point, and no evidence was provided supporting the notion that high intensity thinning to very low basal areas increased resilience or prolonged treatment effectiveness. In fact the opposite effect was depicted, as that synopsis cited a study from northern Arizona where "*higher-intensity treatments were found to have twice the number of ponderosa pine seedlings as low-intensity restoration treatments*,"[11] an example of where aggressive thinning may encourage dramatic increases in ladder fuels.

The Center rejects a framework which assumes that complex ecosystems can be wrangled into fixed proportions of tree ages and sizes that must be repeatedly tinkered with at 30-year rotations to maintain "desired conditions." In areas where strategically located mechanical intervention is implemented, fire alone can and should be the primary future maintenance tool.[12] Measuring the health of the forest on the basis of density-metrics represents a worn-out allegiance to a past industrial paradigm. This regulated-forest model defines successful restoration as growing large, defect-free trees as quickly as possible and ignores the complexity of process-centered ecosystem function. Restoring a forest is not an exercise in

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[8] p. 1424 in Allen *et al.* 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. *Ecological Applications* 12(5): 1418-1433.

[9] p. 1988 in Reinhardt *et al.* 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. *Forest Ecology and Management* 256: 1997-2006.

North *et al*. 2012. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. *Journal of Forestry* 110(7): 392-401.

[10] Yocum 2013. Fuel Treatment Longevity. Ecological Restoration Institute Working Paper No. 27.

[11] p. 5 in Yocum 2013

[12] North *et al.* 2012
Reinhardt *et al.* 2008

manipulating every quantifiable metric into a neat category, or alleviating any form of stress that might lead to unexpected mortality. Renowned fire ecologist Dr. Pete Fulé stated that "*The fire-related adaptations of pine forests are associated with fire's role as a selective force going far back in evolutionary time*,"[13] suggesting that restoration of fire adapted dry forests is inseparable from the influence of recurrent fire as a primary selective force.

The effect of mechanical thinning to very low density and basal area on drought resistance in ponderosa pine and mixed conifer forests has not been studied in long-term, replicated studies with broad geographic inference, and as such, is poorly understood.[14] Ecologists with USGS and USFS recently stated that "*the utility of basal area reduction for minimizing drought impacts in natural forests remains relatively unexplored, especially in dry forests like those of the Southwest US that may be particularly vulnerable to drought*."[15] There has been very little research to date assessing the effect of dramatic canopy reduction on soil heating and drying, which are significant concerns to forest managers. A study from the Fort Valley Experimental Forest found that stands thinned to basal areas of 30 to 100 $ft^2$/acre supported favorable microenvironments for early seedling establishment of ponderosa pine.[16] However, the study did not conclude that the 'low density' treatments (30 $ft^2$/acre) were any more effective than the 'moderate' density treatments (100 $ft^2$/acre) at providing conditions conducive to regeneration. Interestingly, the researchers found that basal area was negatively correlated to seedling survival. This finding suggests that excessively heavy thinning treatments will likely cause overly successful regeneration - a significant management challenge if prescribed or managed fire is not frequent enough to prevent development of dangerous ladder fuels, a phenomenon evident in many areas within the Rim Country footprint. Ongoing studies at the same site have not observed a clear correlation between lower basal area treatments and increased soil moisture during the critical pre-monsoon moisture deficit, and several years of additional data collection may be needed in order to identify any potential relationships.[17]

Complicating the translation of best available scientific information into management direction is the lack of consistency among key descriptors of forest density, especially as it relates to the effects of mechanical thinning on tree ecophysiology and soil-water/drought relationships. Such was the case with Petrie and colleagues research which suggests that 'intermediate' level thinning that minimizes soil surface temperatures will likely promote survival of ponderosa pine seedlings under climate change driven temperature rise.[18] While they do not provide any clarity on what 'intermediate' thinning constitutes, it is noteworthy that they did not suggest 'low' density thinning as a panacea for drought resistance. Another example can be found with Zou and colleagues, who studied soil water dynamics in 'low-density' and

[13] p. 528 in Fulé 2008. Does it make sense to restore wildland fire in changing climate? *Restoration Ecology* 16(4): 526-531.
[14] D'Amato *et al.* 2013. Effects of thinning on drought vulnerability and climate response in north temperate forest ecosystems. *Ecological Applications* 23(8): 1735-1742
[15] p. 12 in Bradford and Bell. 2017. A window of opportunity for climate-change adaptation: easing tree mortality by reducing forest basal area. *Frontiers in Ecology and the Environment* 15(1): 11-17
[16] Flathers *et al.* 2016. Long-term thinning alters ponderosa pine reproduction in northern Arizona. *Forest Ecology and Management* 374: 154–165.
[17] Personal communication; J. Bradford and C. Andrews, U.S. Geological Survey, April 24, 2018.
[18] Petrie *et al.* 2017. Climate change may restrict dryland forest regeneration in the 21st century. *Ecology* 98(6): 1548-1559.

'high-density' ponderosa pine stands at 7,550 ft. on the Pajarito Plateau of New Mexico[19]. They found that over a 4-year period, the 'low-density' stand had an order of magnitude more water available on a per-tree basis than did the 'high-density' stand. It is important to note the condition of the two stands: the 'high-density' stand had 2710 trees/hectare (1120 trees/acre) while the low-density stand had 250 trees/hectare (103 trees/acre). These results suggest that thinning down to moderate densities at the upper end of the USFS's self-crafted "Desired Conditions"[20] is effective at increasing soil water significantly, and provide another example of how the scale of densities reported in research is not necessarily consistent with ranges debated within management dialogue or proposed within EDR.

Bradford and Bell studied the interactions between tree basal area and climate across 1,854 Forest Inventory and Analysis plots in Arizona, New Mexico, Utah, Colorado, and Wyoming[21]. They found strong evidence that tree mortality is positively related to 'high' stand basal area for ponderosa pine and Douglas-fir, and that managing to 'lower' basal areas may decrease future climate-induced mortality due to high temperatures and low moisture predictions. However, their study did not define 'high,' 'medium,' and 'low' basal areas, which essentially precludes managers from translating the results into actionable guidelines. Supplemental charts provided on-line by the researchers did not provide clarity, as there are no labels noting whether density was reported in metric or standard units. As another example, Kerhoulas and colleagues found that 'heavy thinning' of ponderosa pine stimulated growth, improved drought resistance, and provided greater climate change resilience[22]. Again, the definition of 'heavy' is not standardized, and in this case 'heavy thinning' equated to thinning down to approximately 70 $ft^2$/acre of basal area, while 'moderate thinning' was down to ~80 $ft^2$ /acre and 'light thinning' was down to ~98 $ft^2$. Their definition of 'heavy thinning' is near the upper level of basal area prescribed under current 4FRI and Regional direction. Overall, the effects of thinning to the low end of basal area range on soil surface temperatures, soil drying during pre-monsoon drought, and related variables has not been adequately studied. Until scientists can provide clear answers, caution is warranted.

Stand and tree-level growth modelling of EDR treatments by the USFS does not account for the effects of frequent prescribed or natural fires on density, spatial aggregations, fuel profiles, and other variables. In the process of returning fire to the landscape there will be situations where high rates of mortality will occur, even in thinned stands. Frequent fire will lead to formation of fire scars on an unknown proportion of trees which may have a long-lasting influence on mortality as scarred trees break, burn-through, or are otherwise weakened. Excessively heavy thinning to very low basal area, combined with incidental mortality resulting from initial entry fire and attendant soil heating and drying, may possibly promote conversion to non-forest vegetation types. Until appropriately scaled low-density thinning is implemented and studied in a statistically robust research design, it is premature to claim that heavy thinning to the low end of the range will promote climate resiliency or treatment durability any more than less intense treatments.

[19] Zou *et al.* 2008. Soil water dynamics under low-versus high-ponderosa pine tree density: ecohydrological functioning and restoration implications. *Ecohydrology* 1: 309-315.

[20] The Rim Country proposed action (Table 2, page 6) gives a range of 11-124 trees per acre and basal area of 20-80 BAF as Desired Conditions for ponderosa pine forest types. These ranges match what was reported in GTR-310.

[21] Bradford and Bell 2017

[22] Kerhoulas *et al.* 2013. Managing climate change adaptation in forests: a case study from the U.S. Southwest. *Journal of Applied Ecology* 50: 1311–1320.

The cumulative effects of re-establishing frequent fires should not be understated and must be thoroughly assessed in the Rim Country effects analysis. Even with cool, low-severity burns, post-treatment mortality may range between 10% and 30% of the residual trees.[23] As an example, the photo below shows a portion of the GTR-310 Bluewater demonstration site on the Cibola National Forest, New Mexico. The 73-acre site was thinned to <32 $ft^2$/acre and ~25 trees/acre[24] in 2010. Despite the very low density of the remaining forest, a patch of more than 50 trees across 2 acres were killed by the first fire entry following thinning. This unexpected incident of torching led to the death of at least three old-growth trees and calls into question the efficacy of attempts to restore desired structure without consideration of the aggregate effects of re-establishing frequent fire.

*A 2 acre patch of mortality at the GTR-310 Bluewater Demonstration site following initial prescribed fire re-entry, July 2017*

In response to the shortcomings inherent in restoration projects which rely on extensive mechanical thinning, government and academic scientists have called for reconsideration of the strict adherence to historic structural attributes as the clearest pathway towards building resilience into dry fire-adapted forests. Williams and colleagues suggested that in the dynamic context of climate change threatening the sustainability of transitional environments, restoration "*must move beyond frameworks where historic structure and composition are fixed targets for recovery.*"[25] Similarly, Millar and colleagues stated that "*attempts to maintain or restore past conditions require increasingly greater inputs of energy from managers and could create forests that are ill adapted to current conditions and more susceptible to undesirable changes… Decisions that emphasize ecological process, rather than structure and composition, become critical.*"[26] The *Strategic Treatments for Fire Use Alternative* is consistent with that framework, and more in line with widely accepted principles for ponderosa pine forest restoration[27] than the approach currently codified in the Rim Country proposed action.

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[23] Fulé *et al*. 2005. Pine-oak forest dynamics five years after ecological restoration treatments. *Forest Ecology and Management* 218: 129–145; Fulé *et al*. 2007. Posttreatment tree mortality after forest ecological restoration, Arizona, United States. *Environmental Management* 40: 623-634

[24] July 2017 Center for Biological Diversity field inventory of 13 paired 1/10th-acre and 1-acre inventory plots.

[25] p. 21293 in Williams *et al.* 2010. Forest responses to increasing aridity and warmth in the southwestern United States. *Proceedings of the National Academy of Sciences* 107(50): 21289-21294.

[26] pp. 2145-2146 in Millar *et al.* 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications* 17(8): 2145-2151.

[27] See Allen *et al.* 2002

**Impediments to Implementation Threaten Viability of 4FRI as Originally Envisioned**

The *Strategic Treatments for Fire Use Alternative* seeks to achieve a realistic, attainable outcome where values-at-risk are protected from undesirable fire effects, while natural process-structure interactions drive ecosystem restoration and improve resiliency. This approach is badly needed in the Rim Country EIS. The status quo formula of effects analysis is fundamentally flawed, because it assumes that 100% of the potentially treatable area receives assigned prescriptions within the expected time line. Based on current trends, it is highly unlikely that such an outcome can be achieved. Therefore, it is reasonable and prudent to consider an intermediate approach, whereby a subset of strategically located treatments can be implemented in order to facilitate fire-based restoration across the broader landscape. Such an approach was the basis of the *Statewide Strategy to Restore Arizona's Forest*s and the *Landscape Restoration Strategy* for the first 4FRI analysis area.

Leading fire scientists and managers have stated that nationwide "*The current priority and pace of fuels treatments outside the WUI is unlikely to significantly influence fire intensity and severity*."[28] Across the western United States, fuels reduction and forest restoration treatments are not keeping up with the historic fire return intervals for National Forest lands, including dry southwestern forests, resulting in a continued 'fire-deficit' where only about 50% of the required disturbance occurs on an annual basis.[29] The persistent disturbance deficit is a relic of failed past land management practices of commercial logging, fire suppression, grazing, and road building,[30] and continues to generate negative outcomes resulting from compensatory management responses, such as continued fire suppression.[31] Because of economic, legal, and logistical limitations which restrict effective large-scale implementation,[32] a full suite of techniques should be utilized to achieve restoration objectives, including dramatically increased use of prescribed fire and expanding the use of unplanned ignitions for resource benefit.[33]

Palpable, ongoing failures implementing timely and at scale mechanical treatments across much of the 4FRI footprint call into question the USFS's ability to accomplish accelerated landscape-scale restoration. These include: the loss of millions of dollars in just a few years by selected 4FRI contractors;[34] the inability of those contractors to complete more than a tiny fraction of contracted thinning;[35] USFS errors in basic record-keeping;[36] and soaring costs of implementation that exceed even the most well-crafted subsidy funding mechanisms.[37] Concerns surrounding the selection and capacity of the original and

[28] p. 393 in North *et al.* 2012.

[29] Vaillant and Reinhardt 2017. An evaluation of the Forest Service hazardous fuels treatment program—are we treating enough to promote resiliency or reduce hazard? *Journal of Forestry* 115(4): 300-308.
Personal communication: Tessa Nicolet, USFS Region 3 Fire Ecologist, Sept. 23, 2017.

[30] Kauffman 2004. Death rides the forest: perceptions of fire, land use, and ecological restoration of western forests. *Conservation Biology* 18(4): 878-882.

[31] Calkin *et al.* 2015. Negative consequences of positive feedbacks in US wildfire management. *Forest Ecosystems* 2:9.

[32] Collins *et al.* 2010

[33] Stephens *et al.* 2009. Fire treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. *Ecological Applications* 19(2): 305-320.
North *et al.* 2015b.

[34] Arizona Republic, December 10, 2017: "Conservationists boost logging to restore national forests…"

[35] Arizona Daily Sun, January 31, 2018: "Flagstaff-area forest thinning falters"

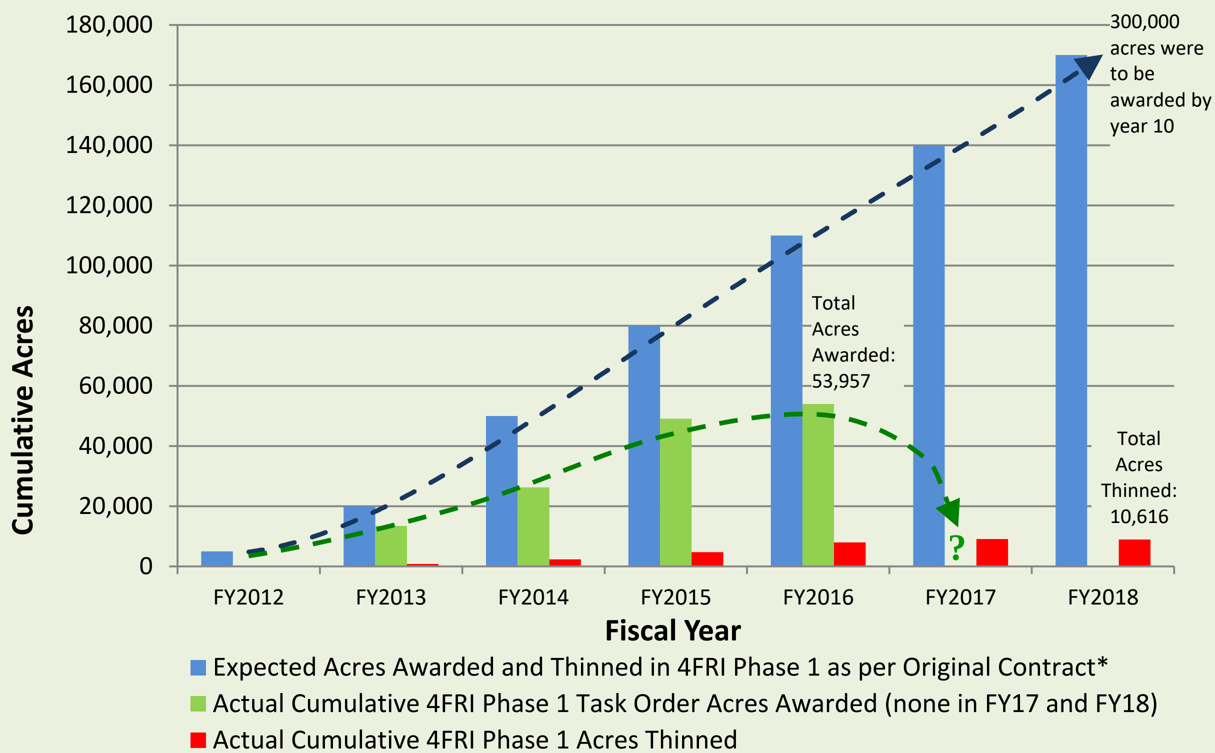
[36] Arizona Daily Sun, April 17, 2018: "Two steps forward, one step back at restored springs south of Flagstaff"

[37] Arizona Daily Sun, February 11, 2018: "City: $10 million bond not enough to cover Flagstaff forest thinning"

successive 4FRI contractors[38] and a marked lack of USFS progress making sufficient acreage available to attract new industry, have also contributed to the current cloud of uncertainty over who can and will complete the actual work of forest restoration.[39] The trend in implementing 4FRI supports our position that "*The backlog of areas in need of restoration combined with limited budgets requires that projects are implemented according to a prioritization system*."[40]

As illustrated in the figure below in red, since 2013, only 10,616 acres have been completed out of the 53,957 acres awarded to contractors for the first phase of 4FRI[41], an annual rate of around 2,000 acres per year. This amount equates to roughly 6% of the 170,000+ acres that would have been mechanically treated at this point in the original contract, had the original contractor not failed in meeting contractual obligations. These implementation rates do not meet expectations of 4FRI Stakeholders and more importantly, cannot meet the project purpose and need in a timeframe commensurate with the current forest health predicament.[42] This situation clearly undermines the validity of an effects analysis predicated on flawed assumptions of on the ground accomplishments.

**Expectations Meet Reality: Acres Awarded and Thinned in the 4FRI Phase 1 Contract**




* Expected acres data derived from USFS Contractor Selection Document which states: Contractor [Pioneer Forest Products] *"will begin implementation 7 to 8 months after the contract award. They proposed to begin with about 5,000 acres the first year and increase the rate of treatment to 30,000 by year 3."* Year 2 (FY2013) value of 15,000 acres is an estimate of "ramping up" from 5,000 to 30,000.

[38] High Country News, September 1, 2014: "Lost in the woods: how the Forest Service is botching its…"
[39] Arizona Daily Sun, February 13, 2018: "Forest Service puts new 4FRI large-scale thinning contract on hold"
[40] p. 1 in Ager *et al.* 2013. Restoration of fire in managed forests: a model to prioritize landscapes and analyze tradeoffs. *Ecosphere* 4(2): 1-19.
[41] Table 3, 4FRI Monthly Update – Mechanical Thinning, Fire, and NEPA – March 2018
[42] It is important to note that significant acreage within the 4FRI footprint has been treated by White Mountains restoration businesses that preexisted 4FRI, utilizing projects authorized outside of the 4FRI EIS project area.

## II. A PATHWAY TO RETURN TO FOUNDATIONAL 4FRI PRINCIPLES

The Rim Country proposed action does not include language enabling treatment prioritization or strategic placement across the 1,240,000 acre analysis area. This is in spite of the clear fact that such an approach has been a consensus element of 4FRI since its inception more than a decade ago. Prominent fire scientists and managers are increasingly calling for strategically placed treatments on portions of the landscape in order to safely facilitate the use of prescribed and managed wildfire to achieve restoration of frequent fire adapted ecosystem processes, composition, and structure. USFS researchers have established that any science-based planning should ask "*Which locations provide the greatest strategic opportunity for fuel treatments that would facilitate attainment of desired conditions*?"[43] The *Strategic Treatments for Fire Use Alternative* asks this important question. One of the Nation's foremost forest restorationists has stated that "*restoration of surface fire in most sites and thinning in strategic sites will increase resistance to severe wildfire at the stand and landscape scales, insect pathogens, and invasive non-native species.*"[44] The Center agrees with that assertion and believes that 4FRI should approach the Rim Country analysis within such a framework. We therefore request the USFS to analyze the *Strategic Treatments for Fire Use Alternative* as a standalone alternative in the 4FRI Rim Country analysis.

By integrating the fire behavior modelling methodologies used in the first 4FRI EIS with treatment optimization simulations, the *Strategic Treatments for Fire Use Alternative* builds upon the work already underway by the USFS and eliminates any perceived need to "reinvent the wheel." The *Strategic Treatments for Fire Use Alternative* also provides appropriate opportunities for implementing the Extended Duration Treatments modification and the Flexible Toolbox Approach in ways that do not compromise consensus-based decision making and the existing 4FRI social contract. The additional analytical overlays that define the *Strategic Treatments for Fire Use Alternative* would prioritize treatment areas following a treatment optimization technique developed by scientists at the Earth Systems Ecology Lab at the University of New Mexico (the Hurteau Lab). Their research[45] has developed "*prioritization strategies for implementing fuel treatments… with the goal to maximize treatment efficacy using optimal placement and prescription options under typical and extreme fire weather conditions*." [46] We propose a tiered implementation structure that combines existing treatment direction, optimized treatment locations, and fundamental 4FRI principles to define three zones with distinct management approaches. This approach could inform landscape-scale restoration planning nationwide, as "*Testing of strategic placement of treatments by resource managers will add data in the years ahead and provide information that can be shared and applied in other locations*."[47] A full description of the *Strategic Treatments for Fire Use Alternative* framework is provided in Section V of this document.

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[43] Peterson and Johnson 2007. Science-based strategic planning for hazardous fuel treatments. *Fire Management Today* 67(3): 13-18.

[44] p. 529 in Fulé 2008

[45] Krofcheck *et al*. 2017a. Prioritizing forest fuels treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. *Global Change Biology DOI: 10.1111/gcb.13913.*

Krofcheck *et al*. 2017b. Restoring surface fire stabilizes forest carbon under extreme fire weather in the Sierra Nevada. *Ecosphere* 8(1): 1-18.

[46] http://www.hurteaulab.org/

[47] p. 15 in Peterson and Johnson 2007

**Current Policy and Guidance Calls For Strategic Treatment Implementation**

In addition to failing to apply the best available scientific information, 4FRI is also failing to address both national fire management policy and foundational principles of the 4FRI charter. The allocation of treatments in the proposed action is overly reliant on mechanical thinning to restore structural attributes to within the historical range of variability. Mechanical restoration treatments, while proven effective to emulate historical structural and compositional attributes,[48] are not the only valid approach to enhancing resiliency, diversity, and function in fire-adapted forests. A range of treatments that can be realistically implemented is required. In a sweeping review of federal fire policy, Stephens and others recommended that the number one improvement that could be made in planning and implementing forest and fire management is to "*mandate evaluation of opportunities for ecologically beneficial fire in land management planning*."[49] The Rim Country analysis would benefit from relaxing the focus on strict structural parameters and utilizing cost-effective means that emphasize fire-based ecological process to establish landscape mosaics and maintain ecological integrity.[50]

The dramatic deficit of annual acreage burned in frequent-fire adapted forests has led senior USFS scientists to call for increasing the scale and rate of fuels treatments following three key strategies:[51] 1) Increasing the extent of fuel treatments if resources permit; 2) Designing treatments to create conditions conducive to naturally ignited fires burning under desired conditions while fulfilling an ecological role; and 3) Placing treatments to reduce hazard while providing options for firefighting when highly valued resources and assets are present. These strategies are becoming widely accepted by fire scientists and managers, but intransigence remains firmly rooted in certain elements of USFS culture.[52]

The *Strategic Treatments for Fire Use Alternative* is rooted in these strategies and demonstrative of the approach promoted in the *National Cohesive Wildland Fire Management Strategy* ("National Strategy").

The National Strategy identifies this general guidance for Vegetation and Fuels Management:[53]

i. **Design and prioritize fuel treatments.** Where wildfires are unwanted or threaten communities and homes, design and prioritize fuel treatments to reduce fire intensity, structure ignition, and wildfire extent.

ii. **Strategically place fuel treatments.** Where feasible, implement strategically placed fuel treatments to interrupt fire spread across landscapes.

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[48] Fulé *et al.* 2012. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine dominated forests help restore natural fire behavior? *Forest Ecology and Management* 269: 68-81.
[49] p. 4 in Stephens *et al.* 2016
[50] Millar *et al.* 2007; Reinhardt *et al.* 2008
[51] p. 301in Vaillant and Reinhardt 2017. An evaluation of the Forest Service hazardous fuels treatment program—are we treating enough to promote resiliency or reduce hazard? *Journal of Forestry* 115(4): 300-308.
[52] Doane *et al.* 2006. Barriers to wildland fire use a preliminary problem analysis. *International Journal of Wilderness* 12(1): 36-38.
North *et al.* 2015b. Reform forest fire management – agency incentives undermine policy effectiveness. *Science* 349(6254): 1280–1281.
Stephens *et al.* 2009. Fire treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. *Ecological Applications* 19(2): 305-320.
[53] pp. 1 and 58 in National Strategy 2014: https://www.forestsandrangelands.gov/strategy/thestrategy.shtml

iii. **Increase the use of wildland fire for meeting resource objectives.** Where allowed and feasible, manage wildfire for resource objectives and ecological purposes to restore and maintain fire-adapted ecosystems and achieve fire-resilient landscapes.

iv. **Continuing and expanding the use of all methods to improve forest and range resiliency.** Continue and expand the use of prescribed fire to meet landscape objectives, improve ecological conditions, and reduce the potential for high-intensity wildfires. Use and expand fuel treatments involving mechanical, biological, or chemical methods where economically feasible and sustainable, and where they align with landowner objectives.

Unlike the current direction of the Rim Country analysis, the *Strategic Treatments for Fire Use Alternative* puts equal emphasis on these four courses of action. These guidelines are mirrored in *The Statewide Strategy for Restoring Arizona's Forests*[54], a seminal document that established the 4FRI framework for landscape-scale forest restoration in Arizona:

"*To meaningfully address restoration, fire, and community protection simultaneously, we must identify strategies for maximizing the effectiveness and efficiency of limited forest management resources. Here we offer four promising management approaches worth serious consideration*:"

*i. Strategically prioritize restoration, fire management, and community protection activities at the landscape-level*

*ii. Strategically place treatments to reduce the threat of landscape-scale fire events*

*iii. Employ prescribed fire and Wildland Fire Use as restoration and fire management tools*

*iv. Employ adaptive management to continually refine management approaches and increase strategic efficiency*

The *Strategic Treatments for Fire Use Alternative* would bring additional focus on the first three approaches – consistent with the National Strategy – which have thus far been not been given adequate attention in formulation of the Rim Country EIS. By focusing limited resources on specific key locations, expanded wildland fire use for resource benefit can be utilized to achieve fuels reduction and ecological restoration objectives. The National Strategy clearly asserts that "*Prescribed fire and managing wildfire for resource objectives have the greatest potential for treating large areas at lower cost than mechanical treatments.*"[55] Researchers have long asserted that "*Prioritizing restoration efforts is essential because resources are limited. An initial focus on areas most likely to provide benefits and that present a low risk of degradation of ecological values will build experience and credibility.*"[56] Prominent fire scientists have recently affirmed that "*Strategically placing fuel treatments to create conditions where wildland fire can occur without negative consequences and leveraging low-risk opportunities to manage wildland fire will remain critical factors to successful implementation of the* [National] *Strategy.*"[57] The *Strategic Treatments for Fire Use Alternative* considers these fundamental principles, and prioritizes mechanical

[54] pp. 10-12 in Statewide Strategy 2007
[55] p. 58 in National Strategy 2014
[56] Brown *et al*. 2004. Forest restoration and fire: principles in the context of place. *Conservation Biology* 18(4): 903-912.
[57] p. 8 in Barnett *et al.* 2016. Beyond fuel treatment effectiveness: characterizing interactions between fire and treatments in the US. *Forests* 7(237): 1-12.

thinning where it would be most effective to ensure community protection, preserve recreational opportunities, and restore predominantly low-intensity fire regimes.

This approach is further called for in the 2012 Mexican Spotted Owl Recovery Plan, which suggests that restoration projects "*Conduct a landscape-level risk assessment to strategically locate and prioritize mechanical treatment units to mitigate the risk of large wildland fires while minimizing impact to PACs*."[58] Additionally, the *Strategic Treatments for Fire Use Alternative* builds on the 2010 *Landscape Restoration Strategy*, which utilized (1) an assessment of current forest conditions, (2) mapping of Firescapes, and (3) fire behavior modeling; resulting in a document that provided "*a proof-of-concept for using a systematic approach to stratify a large analysis area into strategic areas for treatment area identification*" at "*three scales at which landscape-level forest restoration planning should be conducted.*" [59] The *Landscape Restoration Strategy* began when "*the USFS requested information regarding…identification and prioritization of treatment areas,*"[60] and it successfully identified areas that 4FRI Stakeholders considered the highest-priority for treatment. A similar process – consistent with ecological restoration principles – is needed in the Rim Country analysis. These are essential components of landscape scale restoration that have not been given adequate attention in 4FRI but are foundational in the National Strategy, long-standing 4FRI guiding documents, the Mexican Spotted Owl Recovery Plan, and the latest advances in science-based landscape scale planning.

## III. SUCCESSFUL IMPLEMENTATION OF RIM COUNTRY REQUIRES EXPANDING THE USE OF FIRE

Abundant evidence points to the success of fuels reduction treatments including thinning, burning, and combinations of the two at restoring natural fire behavior,[61] even though restoration treatments may not produce significant changes in mean diameter, canopy base height, surface fuels, spatial aggregation, or vertical heterogeneity.[62] Despite the benefits accrued from thinning treatments, restoration of fire-adapted natural and human communities in the Rim Country landscape will require a substantial increase in the area burned annually. Fortunately, the Rim Country landscape is ideally positioned to accomplish this, as current management direction is strongly supportive of enhanced fire use. Three examples illustrate how the Rim Country landscape is moving towards wider deployment of fire:

1) Barnett and colleagues assessed nearly 4,000 wildland fires, more than 136,000 individual fuel treatments, and their interactions across ecoregions of the continental United States[63]. While less than 7% of fuels treatments nationwide were later encountered by a wildfire, the rate rose to more than 30% for the Mogollon Rim Ecoregion where there were >720 instances across >21,000 hectares where a wildfire encountered an area treated by thinning, burning, or combination thereof.

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[58] p. 262 in USFWS 2012 Mexican Spotted Owl Recovery Plan, First Revision (*Strix occidentalis lucida*). Southwest Region U.S. Fish and Wildlife Service Albuquerque, New Mexico.
[59] p. 5 in Landscape Restoration Strategy 2010
[60] p. 4 in Landscape Restoration Strategy 2010
[61] Fulé *et al.* 2012
[62] Ziegler *et al.* 2017. Spatially explicit measurements of forest structure and fire behavior following restoration treatments in dry forests. *Forest Ecology and Management* 386: 1-12.
[63] Barnett *et al.* 2016

2) Among USFS Regions, Vaillant and Reinhardt found that the Southwest (Region 3) is far ahead of the rest of the country in returning fire to the landscape[64]. Their analysis showed that Region 3, compared to the 6 other western Regions, has proportionally the most acres burned by characteristic severity wildfire, the smallest deficit of land area needing treatment to match historical acreage-burned, and the least amount of area being mechanically treated

3) The March 2018 4FRI Monthly Update of Mechanical Thinning, Fire, and NEPA projects lists 442,952 acres of Prescribed Fire and Wildfire with Beneficial Effects occurring between 2010 and 2017 across the four 4FRI National Forests, compared with 185,899 acres of mechanical thinning.

These robust macro-scale analyses and real data confirm that the Southwest Region - and the 4FRI Forests in particular - are ahead of the rest of the nation in returning fire to the landscape, often with beneficial outcomes as determined by proportion of the area burning at characteristic historic fire-severity. The *Strategic Treatments for Fire Use Alternative* would position 4FRI to build upon this trend.

Resource benefit fires tend to cover far more acres than do thinning and prescribed fire treatments.[65] Large treatments can be more effective at moderating fire behavior relative to smaller treatments because they contain more interior area and less edge and are more likely to be encountered by a wildfire.[66] Large fire footprints are more effective at modifying future fire activity than small fires and generally reduce the size of subsequent overlapping burns that occur within ten years of the initial fire, which increases manageability and benefits of subsequent fires.[67] Strategically placed treatments that facilitate the management of wildfire for resource benefit can lead to the required increases in annual wildfire acres burned.[68] Breaking the typical cycle of management reaction and suppression response by increasing the scale and frequency of large prescribed and resource benefit fire use will support sustainable feedback mechanisms whereby future suppression efforts, even in severe fire-weather events, become less necessary.[69] Because the Southwest has entered an era of longer, hotter, drier, and unpredictable fire seasons, it is critical that fire use is accelerated in order to reduce fuels, restore ecosystem process, create landscape heterogeneity, and reduce the impact and severity of the next big blaze beyond the horizon.

**Evidence of Mixed Fire Severities in Southwestern Frequent-Fire Forests**

Multiple lines of evidence support the occasional occurrence of fire effects outside the traditionally accepted notion that low-severity fire was characteristic of southwestern middle elevation forest types. This section discusses this growing body of evidence and is specifically focused on southwestern ponderosa pine and ponderosa pine dominated dry mixed-conifer ecosystems. Because the occurrence of mixed-severity fire is now recognized as within the historical range of variability for these forests, and there are noteworthy advantages of such effects (discussed in Section IV), there is valid scientific support

[64] Vaillant and Reinhardt 2017
[65] Hunter *et al.* 2011. Short- and long-term effects on fuels, forest structure, and wildfire potential from prescribed fire and resource benefit fire in southwestern forests, USA. *Fire Ecology* 7(3): 108-121.
[66] Barnett *et al.* 2016
[67] Teske *et al.* 2012. Characterizing fire-on-fire interactions in three large wilderness areas. *Fire Ecology* 8(2): 82-106.
[68] Vaillant and Reinhardt 2017
[69] Calkin *et al.* 2015. Negative consequences of positive feedbacks in US wildfire management. *Forest Ecosystems* 2:9.
North *et al.* 2015b

for utilizing it as a restoration tool *where appropriate and feasible in a manner that does not put communities, infrastructure, and other key values at risk.*

The historical phenomenon of stand-replacing fire and attendant debris flows in ponderosa pine dominated mixed-conifer forests have been recorded at Kendrick Mountain on the Kaibab National Forest, Missionary Ridge in the San Juan Mountains of Colorado, The Jemez Mountains of New Mexico, at Rio Puerco in northern New Mexico, the Sacramento Mountains of New Mexico, and elsewhere throughout the West.[70] While the methods used to age severe fire events cannot suggest the size of such events, these studies uniformly conclude that fire behavior is highly sensitive to relatively modest climatic change and that it is important to include mixed-severity fire at centennial to millennial scales as a component of the natural range of variability. Roos and Swetnam reported that the combined effects of a century long fire-free period (1360 to 1455) punctuated by two unusually wet periods and followed by a hemispheric mega-drought may have led to conditions that supported widespread crown fires in southwestern ponderosa pine forests. They also suggested that similar periods of reduced fire frequency in the eighth, ninth, and sixteenth centuries may have "*led to altered forest structures that were more vulnerable to increased fire severity.*"[71]

Fire history research has provided additional support for mixed fire severities in more recent centuries. Hunter and colleagues reported that high-severity burn patches within moderate severity burn matrixes in ponderosa pine and pinyon-juniper ecosystems on the Gila National Forest were generally smaller than, but up to, 120 hectares.[72] Those findings corroborate Abolt's determinations that historical stand-replacing patches in the Mogollon Mountains ranged from 6 to 103 hectares along an elevational gradient, based off of aged aspen stands.[73] In a fire history study in the Black Mesa Ranger District of the Apache-Sitgreaves National Forest, Huffman and colleagues determined that their 1,300 hectare study site (7,600-7,900 ft.) was dominated by frequent, low-severity fires that maintained a ponderosa pine-dominated mixed conifer plant community. However, they did suggest that fire-induced even-aged regeneration events up to 25 hectares in size did occur historically, based off of spatial patterns of large trees and stumps.[74] Williams and Baker concluded that around 30% of trees survived high-severity fires along the

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[70] Jenkins *et al.* 2011. Late Holocene geomorphic record of fire in ponderosa pine and mixed-conifer forests, Kendrick Mountain, northern Arizona, USA. *International Journal of Wildland Fire* 20: 125-14

Bigio *et al.* 2010. A comparison and integration of tree-ring and alluvial records of fire history at the Missionary Ridge Fire, Durango, Colorado, USA. *The Holocene* 20(7): 1047-1061.

Fitch 2013. Holocene fire-related alluvial chronology and geomorphic implications in the Jemez Mountains, New Mexico. M.S Thesis, University of New Mexico, Albuquerque, NM.

Meyer and Frechette 2010. The Holocene record of fire and erosion in the southern Sacramento Mountains and its relation to climate. *New Mexico Geology* 32(1): 19-21.

French *et al.* 2009. Holocene alluvial sequences, cumulic soils and fire signatures in the middle Rio Puerco basin at Guadalupe Ruin, New Mexico. *Geoarchaeology* 24(5): 638-676.

Pierce and Meyer 2008. Late Holocene records of fire in alluvial fan sediments: fire-climate relationships and implications for management of Rocky Mountain forests. *International Journal of Wildland Fire* 17*:* 84-95.

[71] p. 288 in Roos and Swetnam 2011. A 1416-year reconstruction of annual, multidecadal, and centennial variability in area burned for ponderosa pine forests of the southern Colorado Plateau region, Southwest USA. *The Holocene* 22(3): 281-291.

[72] Hunter *et al.* 2011

[73] Abolt 1997. Fire histories of upper elevation forests in the Gila Wilderness, New Mexico via fire scar and age structure analysis. MS Thesis, University of Arizona, Tucson, AZ.

[74] Huffman *et al.* 2015. Fire history of a mixed conifer forest on the Mogollon Rim, northern Arizona, USA. *International Journal of Wildland Fire http://dx.doi.org/10.1071/WF14005*

Mogollon Rim,[75] which was not refuted by Fule and Colleagues, although it led to a robust discussion of what the definition of 'high-severity' really is.[76]

Studies at Grand Canyon, the Mogollon Rim, and the Gila Wilderness are also consistent with research coming from the Sierra Nevada of California. For example, a study at Illilouette Creek Basin in Yosemite National Park (4,600-9,900 ft.) determined that in Jeffrey pine and mixed conifer forests that have seen a return to near-normal fire regimes, high-severity patch sizes made up 15% of burned areas, and were typically less than 4 hectares, with occasional patches up to 60 hectares.[77]

The restoration of functional natural fire processes in the future is likely to regulate ecosystem structure and composition[78] and re-establish a new dynamic equilibrium that tracks climate effects on vegetation and landscape pattern in real time.[79] Cutting-edge research has concluded that these small patches of near or total mortality contribute to spatial heterogeneity, and may be consistent with historical spatial patterns.[80] After observing the effects of numerous resource benefit fires in the Gila Wilderness, Holden and colleagues concluded that fire-caused openings ranged in size from 0.25 to 20 hectares and that "*most of the risks, in terms of mortality to medium- and large-diameter trees are associated with the first fire after long periods of fire exclusion.*"[81]

Traditionally, the extensive body of literature surrounding restoration of ponderosa pine and dry mixed-conifer ecosystems has supported the notion that fires burned almost exclusively at low-severities. In a seminal paper on the subject, Moore and colleagues stated that "*low-frequency, high intensity stand replacement fires were very rare or nonexistent.*"[82] However, a growing body of research during intervening years, described here, suggests that a mix of severities have historically occurred across landscapes similar to or including the Rim Country area. For example, Owen and colleagues stated frankly that "*ponderosa pines evolved under fire regimes dominated by low- to moderate-severity wildfire*"[83] which is a substantial philosophical departure from Moore and colleagues' statement.

[75] Williams and Baker 2012. Spatially extensive reconstructions show variable severity fire and heterogeneous structure in historical western United States dry forests. *Global Ecology and Biogeography* 21(10): 1042-1052.

[76] Fulé *et al.* 2014. Unsupported inferences of high-severity fire in historical dry forests of the western United States: response to Williams and Baker. *Global Ecology and Biogeography* 23: 825-830.

[77] Collins and Stephens 2010. Stand-replacing patches within a 'mixed-severity' fire regime: quantitative characterization using recent fires in a long-established natural fire area. *Landscape Ecology* 25: 927-939.

[78] Parks *et al.* 2015. Wildland fire as a self-regulating mechanism: the role of previous burns and weather in limiting fire progression. *Ecological Applications* 25(6): 1478-1492.

[79] Falk 2006. Process-centered restoration in a fire-adapted ponderosa pine forest. *Journal for Nature Conservation* 14: 140-151.

[80] Iniguez *et al.* 2009. Spatially and temporally variable fire regime on Rincon Peak, Arizona, USA. *Fire Ecology* 5: 3-21.

Margolis and Balmat 2009. Fire history and fire-climate relationships along a fire regime gradient in the Santa Fe Municipal Watershed, NM, USA. *Forest Ecology and Management* 258: 2416-2430.

Sensibaugh and Huffman 2014. Managing naturally ignited wildland fire to meet fuel reduction and restoration goals in frequent-fire forests. Ecological Restoration Institute Fact Sheet.

[81] p. 28 in Holden *et al.* 2007. Effects of multiple wildland fires on ponderosa pine structure in two southwestern wilderness areas, USA. *Fire Ecology* 3(2): 18-33.

[82] p. 1269 in Moore *et al.* 1999. Reference conditions and ecological restoration: a southwestern ponderosa pine perspective. *Ecological Applications* 9(4): 1266-1277.

[83] p. 134 in Owen *et al.* 2017. Spatial patterns of ponderosa pine regeneration in high-severity burn patches. *Forest Ecology and Management* 405: 134-149.

Additionally, Fulé and colleagues, in their noteworthy response to Williams and Bakers[84] claims of widespread high-severity fires in northern Arizona's forests, stated that "*historical fires in relatively dry forests dominated by ponderosa pine included a range of fire severities*."[85]

Increased frequency, extent, and severity of wildland fires may attend climate warming and increasing drought.[86] Numerous research approaches using a range of modelling techniques suggest that widespread conifer mortality, diminished recruitment opportunities, and high-severity fire feedbacks will reduce the range and sustainability of southwestern forested ecosystems.[87] Ponderosa pine forests have survived past mega-droughts and protracted mortality events, however,[88] suggesting that resilience-to and recovery-from extreme perturbations may be driven by complex multidirectional relationships between disturbance and abiotic and biotic factors.[89] Extreme droughts driving widespread mortality events can be followed by profoundly wet periods where fire frequency declines and tree recruitment increases.[90] Extensive bark beetle outbreaks, such as those which repeatedly occurred on the Kaibab Plateau up to the period of fire-suppression initiation,[91] can create large openings within the forest canopy, which may have increased fire severity at the patch scale as downed logs were consumed.

This evolution of our understanding of drought, insects and diseases, and occasional mixed-severity fire occurring at limited scales within the natural range of variability, as well as the utility of such fires in restoring forest structure, provides needed justification for concerns that arise from expanding the use of fire to achieve beneficial outcomes. Based on these studies, prescribed and resource benefit fires could mimic historical fire behavior by accepting higher levels of mortality in patches of up to 100 hectares in ponderosa pine, and perhaps up to several hundred or more in mixed-conifer forests during the initial fire entry, *and only in areas where such fires can be managed to protect communities, infrastructure, and other key values*.

[84] Williams and Baker 2012
[85] p. 827-828 in Fulé *et al.* 2014
[86] Seager and Vecchi 2010. Greenhouse warming and the 21st century hydroclimate of southwestern North America. *Proceedings of the National Academy of Sciences* 107(50): 21277-21282.
Williams *et al.* 2010
[87] Savage *et al.* 2013. Double whammy: high-severity fire and drought in ponderosa pine forests of the southwest. *Canadian Journal of Forest Research* 43: 570-583.
McDowell *et al.* 2015. Multi-scale predictions of massive conifer mortality due to chronic temperature rise. *Nature Climate Change*
Petrie *et al.* 2017
Williams *et al.* 2010
[88] Brown and Wu 2005. Climate and disturbance forcing of episodic tree recruitment in a southwestern ponderosa pine landscape. *Ecology* 86(11): 3030-3038.
[89] Puhlick *et al.* 2012. Factors influencing ponderosa pine regeneration in the southwestern USA. *Forest Ecology and Management* 264: 10-19.
[90] Brown and Wu 2005
[91] Lang and Stewart 1910. Reconnaissance of the Kaibab National Forest. Available on-line at www.nau.edu/library/speccoll/manuscript/kaibab_recon.
Craighead 1924. The black hills beetle practicing forestry on the Kaibab. *Forest Worker*, November, 1924: 74.
Craighead 1925. The *Dendroctonus* problem. *Journal of Forestry* 23: 340-354.

**Benefits of Mixed-Severity Fires in Southwestern Frequent-Fire Forests**

Implementing a strategic approach to facilitate the expanded use of prescribed and resource benefit wildfire includes a greater acceptance of mixed-severity fire across all vegetation types in the Rim Country landscape. In this section, we review the state of our understanding of how mixed-severity fire can be a useful tool to achieve beneficial ecological outcomes. As described in the next section, sufficient evidence exists to support the occurrence of a range of fire effects in the evolutionary environment at multiple temporal scales. The diversity of fire effects is driven by factors that are common on the Rim Country landscape, such as topographic variation, disturbance history, vegetation characteristics, and proximity to values-at-risk. Because wildland fire use has been increasingly used throughout the west, research on its ecological and practical benefits has multiplied. An extensive body of science now points towards a wide range of fire intensities and severities as a critical driver of ecological restoration and fuels reduction success.

*Reducing fuels and restoring historic structure.*

Agee and Skinner suggested that prescribed fire is generally effective at reducing surface fuels and raising canopy base height, but because of undesirable "severity thresholds" reductions in crown density were less easy to achieve.[92] Implementing the *Strategic Treatments for Fire Use Alternative* requires reconsideration of acceptable severity thresholds. A growing body of research from dry, frequent-fire adapted forests supports the use of moderate-severity prescribed and/or natural-ignition fire in a mosaic of severities to achieve fuels reduction objectives, as well as restoring historic structure and pattern. Patchy-mosaics resulting from mixed-severity fire provide timely opportunities to conduct additional prescribed burns while fuel continuity and density have been reduced.[93] Often, subsequent fires burn at lower severity and result in fewer changes to the forest.[94]

Low severity prescribed fire alone may not always reduce canopy density sufficient to meet fuels reduction or ecological restoration objectives.[95] On the Gila National Forest (outside of the Gila Wilderness) moderate-severity resource benefit fire more effectively reduced basal area, tree density, seedling density, crown bulk density, canopy base height, and surface fuel loads than did low-severity prescribed or resource benefit fires in ponderosa pine and pinyon-juniper ecosystems.[96] Because of reductions in crown bulk density and crown base height, moderate-severity resource benefit fires in ponderosa pine and pinyon-juniper ecosystem can be more effective at reducing predicted crown fire potential than low-severity prescribed fires, even under very severe fire weather conditions.[97]

Studying the effects of a mixed-severity fire in ponderosa pine and dry mixed-conifer forest on Kendrick Peak, Kaibab National Forest, Stevens-Rumann and colleagues observed that areas of moderate-severity burn effects with mortality rates generally ranging between 40%-80% had met target basal area thresholds the highest amount of ponderosa pine regeneration, optimum coarse woody debris loadings, adequate fine

[92] Agee and Skinner 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211(1): 83-96.
[93] Williams *et al.* 2010
[94] Holden *et al.* 2007
[95] Stephens *et al.* 2009
[96] Hunter *et al.* 2011
[97] Hunter *et al.* 2011

woody debris to carry a surface fire, and met minimum requirements for snags. The authors concluded that areas where 40-80% tree mortality occurred should be managed with reintroduction of frequent low-severity surface fires to maintain stand structure, and pointed out that these moderate-severity burned areas would be more resilient to future disturbance and would be easier to maintain than thinning overly dense ponderosa pine forests. [98] Similarly, Huffman and colleagues found that across ten single-entry resource benefit fires in northern Arizona, most structural and fuels targets were only met when fire-induced mortality exceeded 31%.[99] Hunter and colleagues compared prescribed and resource benefit fires on the Gila National Forest and their "*results show that a single fire of moderate severity alone can result in stand densities that more closely resemble pre-settlement conditions.*"[100]

Pulses of dead trees resulting from patches of high-severity fire have led to speculation increased fuel loadings may lead to amplified reburn severity. In the Southwest, patches of fire-killed trees can be expected to have fallen and substantially decomposed within one decade,[101] and even in areas of very high mortality coarse woody debris is unlikely to exceed management recommendations for fuel loadings.[102] Studies from the dry forests of the Pacific Northwest have shown that standing dead and dead/down woody debris actually experienced lower severity subsequent fires than salvage logged and replanted sites.[103] Similarly, Meigs and colleagues discovered after analyzing several hundred fires in the Pacific Northwest that burn severity was generally lower in forests with higher cumulative bark beetle damage, and that burn severity continued to decrease with time.[104]

A number of studies have reported inadequate post-fire ponderosa pine regeneration and type-conversion to shrub or grassland habitats with decades-long legacy effects.[105] However, this is not a universal phenomenon. Despite the size of high-severity burn patches in the Rodeo-Chediski fire, ponderosa pine appears to be regenerating in abundance, spatial pattern, and uneven-agedness along a trajectory that is similar to historical structural characteristics, albeit with a higher abundance of sprouting oak and juniper

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[98] Stevens-Rumann *et al.* 2012. Ten years after wildfires: How does varying tree mortality impact fire hazard and forest resiliency? *Forest Ecology and Management* 267: 199-208.

[99] Huffman *et al.* 2017a. Efficacy of resource objective wildfires for restoration of ponderosa pine (*Pinus ponderosa*) forests in northern Arizona. *Forest Ecology and Management* 389: 395-403.

[100] p. 117 in Hunter *et al.* 2011

[101] Roccaforte *et al.* 2012. Woody debris and tree regeneration dynamics following severe wildfires in Arizona ponderosa pine forests. *Canadian Journal of Forest Research* 42: 593-604.

Passovoy and Fulé 2006. Snag and woody debris dynamics following severe wildfires in northern Arizona ponderosa pine forests. *Forest Ecology and Management* 223: 237–246.

Savage and Mast 2005. How resilient are southwestern ponderosa pine forests after crown fire? *Canadian Journal of Forest Research* 35: 967-977.

[102] Stevens-Rumann *et al.* 2013. Pre-wildfire fuel reduction treatments result in more resilient forest structure a decade after wildfire. *International Journal of Wildland Fire* 22: 1108-1117.

[103] Thompson *et al.* 2007. Reburn severity in managed and unmanaged vegetation in a large wildfire. *Proceedings of the National Academy of Sciences* 104(25): 10743-10748.

[104] Meigs *et al.* 2016. Do insect outbreaks reduce the severity of subsequent forest fires? *Environmental Research Letters* 11.

[105] Haire and McGarigal 2008. Inhabitants of landscape scars: succession of woody plants after large, severe forest fires in Arizona and New Mexico. *The Southwestern Naturalist* 53(2): 146-161

Savage and Mast 2005

species. [106] Also on the Rodeo-Chediski Fire, Shive and colleagues reported significantly more ponderosa pine regeneration in high severity burn patches than in low-severity patches.[107]

In spite of the tremendous size of the Rodeo-Chediski Fire – which the Center agrees is dramatically beyond the scale of characteristic fire behavior in the southwestern ponderosa pine forest – the situation today is not as grim as it appeared in the fires immediate aftermath. Leveraging the reduced fuels across the Rodeo-Chediski fire area to return low-intensity prescribed fire would be useful for limiting the degree to which sprouting woody species dominate the post-fire community, breaking up fuel continuity in future fires, and restoring natural frequent fire processes.

*Increasing spatial and temporal heterogeneity.*

Fire and forest structure interact such that the variability in stand structures present within a landscape influences the distribution of fire behaviors and severities, which in turn influence successional trajectories of post-fire environments.[108] The patchy mosaic patterns attributed to historic forest ecosystems were influenced by a range of fires and other disturbances through time and space – including patches of high-severity fire – that "*create coarse-grained, high-contrast heterogeneity…*[and]… *a complex mosaic of seral stages at the landscape and local scales*."[109] Fine scale, site-specific factors can produce dissimilar spatial patterns between sites in close proximity[110] in response to site characteristics, disturbance, successional pathways, and management history.[111]

Fire can create heterogeneity in ways that mechanical approaches simply cannot. A study of eleven mixed-severity Arizona fires across a sixteen year chronosequence described dramatic variability between fires in residual structure, regeneration response, snag and coarse woody debris dynamics, and future trajectories.[112] On the Rodeo-Chediski Fire in Arizona, Shive and colleagues observed that pre-fire treatments combined with mixed fire-severities to produce landscape heterogeneity that defied simple classification by burn severity.[113] On the same fire Owen and colleagues observed unexpected and paradoxical regeneration characteristics that included the highest documented rates of ponderosa pine regeneration occurring intermixed with the highest density of re-sprouting species in a plot far from the nearest pine seed-source.[114] These types of complex spatial arrangements of vegetative successional stages with variations in patch size and shape enhance biological diversity and influence future fire spread

[106] Owen *et al.* 2017
[107] Shive *et al.* 2013. Pre-wildfire management treatments interact with fire severity to have lasting effects on post-wildfire vegetation response. *Forest Ecology and Management* 297: 75-83.
[108] Ziegler *et al.* 2017
[109] p. 310 in DellaSala *et al*. 2014. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? *Natural Areas Journal* 34(3): 310-324.
[110] Rodman *et al.* 2016. Reference conditions and historical fine-scale spatial dynamics in a dry mixed-conifer forest, Arizona, USA. *Forest Science* 62: 268–280.
[111] Hessburg *et al.* 2015. Restoring fire-prone Inland Pacific landscapes: seven core principles. *Landscape Ecology* 30: 1805-1835.
[112] Roccaforte *et al.* 2012
[113] Shive *et al.* 2013
[114] Owen *et al.* 2017

and behavior.[115] Diverse understory communities across a spectrum of disturbance histories and successional trajectories may provide additional resilience to future climate-induced changes.[116]

High-severity burn patches in the Rodeo-Chediski Fire on the White Mountain Apache Reservation in Arizona have been found to have significantly higher forb species richness, total understory plant cover, and ponderosa pine regeneration compared to low-severity areas.[117] A high-intensity escaped prescribed fire in a ponderosa pine dominated mixed-conifer forest at Grand Canyon National Park led to a dramatic increase in understory native plant cover, species richness, and composition.[118] Naturally recovering high-severity burn patches within mixed-severity mosaics have increased plant diversity and may be more resilient to future climate stress.[119]

The contemporary fire crisis is not so much predicated on high-severity fire being inherently "bad," but that the scale of patches exceeds what would have historically occurred. Determining the appropriate scale and frequency of fire-induced patch disturbance is an important step towards harnessing the efficacy of fire to achieve restoration objectives.

*Promoting complex early-successional ecosystems*

Early-successional forest ecosystems possess high structural complexity, spatio-temporal heterogeneity, and biological/foodweb diversity resulting from variability in disturbance severity, environmental conditions, and surviving trees.[120] Patches of moderate to high-severity fire can produce highly spatially variable forest structures as a response to uneven burn effects and patchy mortality dynamics.[121] Tree regeneration patterns in early-successional habitats reflect favorable environmental conditions[122] and variable thinning by fire and other disturbance.[123] These areas of localized disturbances create valuable wildlife habitat[124] and provide opportunities to apply additional fire treatments which promote further spatial diversity.[125]

The common attributes of complex early seral forests include:[126]

- Abundant and widely distributed large trees, snags and downed logs

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[115] Teske *et al.* 2012
[116] Halofsky *et al.* 2011. Mixed- severity fire regimes: lessons and hypotheses from Klamath-Siskiyou Ecoregion. *Ecosphere* 2(4): art40.
Hurteau *et al.* 2014. Climate change, fire management, and ecological services in the southwestern US. *Forest Ecology and Management* 327: 280-289.
[117] Shive *et al.* 2013
[118] Huisinga *et al.* 2005. Effects of an intense prescribed fire on understory vegetation in a mixed conifer forest. *Journal of the Torrey Botanical Society* 32(4): 590-601.
[119] Hunter *et al.* 2011; Owen *et al.* 2017
[120] Swanson *et al.* 2011. The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and the Environment* 9(2): 117-125.
[121] Fulé *et al.* 2004. Effects of an intense prescribed forest fire: is it ecological restoration? *Restoration Ecology* 12(2): 220–230.
[122] Savage *et al.* 1996. The role of climate in a pine forest regeneration pulse in the southwestern United States. *Ecoscience* 3(3): 310-318.
[123] Holden *et al.* 2007
[124] Halofsky *et al.* 2011; Hunter *et al.* 2011
[125] Williams *et al.* 2010
[126] p. 314 in DellaSala *et al.* 2014

•Varied and rich understory flora
•Varied and rich floral invertebrate, avian and mammalian species composition
•Highly complex structural complexity with many biological legacies
•Complex and functional below-ground biological processes
•Complex and varied genetic diversity
•Rich ecosystem processes including pollination and predation
•Low susceptibility to invasive species
•Varied and complex disturbance frequency
•High landscape integrity with shifting mosaics and disturbance dynamics
•High resilience and resistance to climate change due to varied and complex genomes

Haire and McGarigal studied high-severity burn patches at Saddle Mountain (Kaibab Plateau, Arizona; burned in 1960) and La Mesa (Pajarito Plateau, New Mexico; burned in 1977), both of which share similar soils, topography, and vegetative communities as the Rim Country landscape. The purpose of their research was to "*better understand plant succession after severe fire events in the southwestern United States, given the possibility that these landscapes occupy an important place in long-term variability of ecosystems.*"[127] Fifty-two species of native trees and shrubs, arranged along dynamic spatially and temporally influenced gradients, were documented at the two sites. Distance from edge-of-burn was strongly correlated to prevalence of resprouting species (generally shrubs, including oaks) over off-site seeders (generally coniferous trees), and was influenced by conditions in the pre-fire landscape. However, evidence of continued tree establishment and succession was evident decades post-fire as environmental conditions permitted tree establishment.

The early-successional habitats encountered by Haire and McGarigal led to their conclusion that:

*"Areas burned in severe fire at Saddle Mountain and La Mesa included communities that might diversify function of landscapes through creation of early successional habitats for wildlife. In addition, woody species at the study sites have a wide range of traditional and current uses; basketry and other building material important food sources, a plethora of medicinal remedies, and ceremonial uses in contrast to studies that emphasize undesirable effects when forests transition to openings and alternative habitats, our research elucidates the need for further consideration of both young forest communities, and the persistent species and communities described as landscape scars, in conservation plans for forest systems of the southwestern United States.*"[128]

Recent work by Owen and colleagues at the Rodeo-Chediski and Pumpkin Fires confirmed ponderosa pine establishment > 300m from nearest seed source in spatial arrangements that were indistinguishable from forest-edge locations regardless of presence of sprouting woody species, suggesting forest recovery was in fact occurring.[129] Unfortunately, complex early seral forests are poorly understood in southwestern dry forests as reference site studies and stand reconstructions characteristically cannot account for small diameter trees and other small vegetation. In order to maintain biodiversity and support landscape heterogeneity it is imperative that scientists initiate more research on these ephemeral habitats in dry

[127] p. 147 in Haire and McGarigal 2008
[128] p. 159 in Haire and McGarigal 2008
[129] Owen *et al.* 2017

southwestern forests in order to account for their contribution in ecosystem management.[130] Meaningfully increasing the use of prescribed and wildland fire for ecological restoration requires recognition of the benefits of mixed fire severities in shrub, woodland and forested ecosystems. Based on the information presented above, small patches of high-severity fire effects interspersed within a matrix of low and moderate-severity can meet restoration objectives, create important ephemeral habitats, and reduce the risk of uncharacteristic reburn potential.

**Repeated Fire Application in Prescribed and Managed Wildfire Settings is Needed and Reflects the Best Available Science**

The objective of ecological restoration in southwestern fire-adapted forests is to restore resilience to the inevitable future fires that will come, regardless of climate, environmental or human influences.[131] A number of fires have occurred across the Rim Country landscape that can be leveraged for additional gains in fuels reduction and ecosystem restoration. It's a lost opportunity to not follow recent prescribed, resource benefit, and uncontrolled wildfires with additional fire, knowing that past fires act as fuel breaks and that effect diminishes with time.[132] It is critical to remember that "*historical ponderosa pine forest structure was a product of not one but of a series of fires over time*."[133] The compounding effect of recurring fire through centuries was selection for functional traits that incur ecophysiological adaptive benefits for drought and fire tolerance.[134] Overlapping fire mosaics promote development of differential tree recruitment, increase structural diversity and successional pathways, and break up fuel beds, facilitating more beneficial fires in the future.[135]

Holden and colleagues, in an analysis of thirteen fires in the Gila and Aldo Leopold Wilderness areas found evidence that initial wildfire severity slightly influenced severity of subsequent fires. In that study, which did not provide information for the size or distribution of burn patches, initial high-severity burns frequently reburned at high-severities, but most often in moist, high-elevation sites. The authors ultimately concluded that satellite imagery must be interpreted carefully and that field verification of their sites was needed.[136] Later work provided a contrasting conclusion, that previous wildfires do in fact moderate the severity of subsequent fires and lead to proportionally more area burned at low-severity.[137]

Returning frequent fire to the landscape will continue to alter forest structure and composition in ways that are not yet fully known, especially for wildlife that utilize snags and coarse woody debris.[138] Consistently, however, research from throughout the western United States alludes to the efficacy of

[130] Swanson *et al.* 2011
[131] Allen *et al.* 2002
Schoennagel *et al.* 2017. Adapt to more wildfire in western North American as climate changes. *PNAS* doi/10.1073/pnas.1617464114.
[132] Parks *et al.* 2015
[133] p. 118 in Hunter *et al.* 2011
[134] Strahan *et al*. 2016. Shifts in community-level traits and functional diversity in a mixed conifer forest: a legacy of land-use change. *Journal of Applied Ecology*, doi: 10.1111/1365-2664.12737.
[135] Teske *et al.* 2012
[136] Holden *et al*. 2010. Burn severity of areas reburned by wildfires in the Gila National Forest, USA. *Fire Ecology* 6(3): 77-85.
[137] Parks *et al*. 2014. Previous fires moderate burn severity of subsequent wildland fires in two large western US wilderness areas. *Ecosystems* 17: 29-42.
[138] Holden *et al*. 2006. Ponderosa pine snag densities following multiple fires in the Gila Wilderness, New Mexico. *Forest Ecology and Management* 221: 140–146.

returning fire in a mixed-severity approach, and following up with repeated low-severity burning for restoring historical structure, pattern, and process.[139] Modelling by Shive and colleagues showed that under milder climate scenarios, prescribed fire combined with climate-induced growth reductions resulted in ponderosa pine basal areas within the HRV[140], consistent with field observations of fire-based restoration at Grand Canyon and the Gila Wilderness, described below.

Repeated summer wildfires since 1946 at in the Gila and Saguaro Wilderness areas have successfully reduced density of small-diameter trees while not affecting large tree density, effectively shifting towards a larger tree distribution while reducing risk of crown fire, increasing resilience, and creating desired structural heterogeneity.[141] Similar effects have been documented on the Hualapai Indian Reservation, where more than fifty years of frequent prescribed fires have increased resilience to crown fire and climate change near the lower elevational limit of ponderosa pine.[142]

Repeated mixed-severity prescribed and natural-ignition fires in ponderosa pine dominated forests at Grand Canyon National Park have been shown to limit large tree mortality, reduce density of conifer seedlings and shade tolerant understory saplings, and reduce surface fuels consistent with restoration objectives and managing for climate resilience.[143] Initial mortality pulses resulting from initial fire entry create numerous snags, but many are consumed upon fire reentry as snag recruitment and persistence reaches a possible equilibrium.[144]

Studying the effects of prescribed fires on burn severity in the Rodeo-Chediski Fire, Finney and colleagues found that areas which were repeatedly burned significantly reduced subsequent burn severity, but the beneficial effects diminished with time since fire. Their observations of fire progression, captured via satellite, provided evidence "*consistent with model predictions that suggest wildland fire size and severity can be mitigated by strategic placement of treatments*."[145] Researchers observed the same effect studying fires in New Mexico and Idaho, where the "*severity of reburns increases with time since the previous fire, likely due to biomass accumulation associated with longer fire-free intervals.*"[146] Although their data showed that previous fires did have an effect up to 22 years later, further study concluded that initial fires ability to act as a fuel break was as little as 6 years in warm/dry climates such as southwestern ponderosa pine forests.[147]

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[139] Hunter *et al.* 2011

[140] Shive *et al*. 2014. Managing burned landscapes: evaluating future management strategies for resilient forests under a warming climate. *International Journal of Wildland Fire* 23: 915–928

[141] Holden *et al.* 2007

[142] Stan *et al*. 2014. Modern fire regime resembles historical fire regime in a ponderosa pine forest on Native American lands. *International Journal of Wildland Fire* 23: 686-697.

[143] Fulé *et al*. 2002. Natural variability in forests of the Grand Canyon, USA. *Journal of Biogeography* 29: 31-47.
Fulé and Laughlin 2007. Wildland fire effects on forest structure over an altitudinal gradient, Grand Canyon National Park, USA. *Journal of Applied Ecology* 44: 136-146.
Laughlin *et al*. 2011. Effects of a second-entry prescribed fire in a mixed conifer forest. *Western North American Naturalist* 71(4): 557-562; and Fulé *et al.* 2004

[144] Holden *et al.* 2006; Laughlin *et al.* 2011

[145] p. 1714 in Finney *et al*. 2005. Stand- and landscape-level effects of prescribed burning on two Arizona wildfires. *Canadian Journal of Forest Research* 35: 1714-1722.

[146] p. 38 in Parks *et al.* 2014

[147] Parks *et al.* 2015

Repeated resource objective fires on the Kaibab National Forest were recently reported to be more effective at restoring desired structure when they burned at moderate-severity under active fire-weather conditions.[148] Collins and Stephens found that in two Sierra Nevada wilderness areas where fire use policies were adopted, contemporary low-severity fires had allowed forests to become more resistant to insects, drought, and disease despite not having been thinned to historical densities. They concluded that "*what may be more important than restoring structure is restoring the process of fire*…[which] *could be important in allowing these forests to cope with projected changes in climate*."[149]

Collins and colleagues studied mixed conifer forests in Yosemite National Park (4,800 - 7,000 ft.) where up to seven management and lightning started fires burned between 1983 and 2009, following an approximately 80-year fire-free period. They found that recent low severity fires reduced surface fuels and understory trees but did not kill enough intermediate sized trees to move towards desired structural characteristics. Their findings indicated "*no significant differences between current forest structure in areas that burned recently with moderate severity and forest structure in 1911*"[150] which was the year that historical inventory data was available for, and that only moderate fire-severity could substantially alter the ratio of fir to pine trees.

Taylor reported that two late twentieth century fires in an old growth ponderosa pine-Kellogg oak forest in California's Ishi Wilderness were effective at restoring pre-fire-exclusion structural characteristics, including composition, density, basal area and spatial pattern.[151] Similar effects were reported by Larson and colleagues, where reintroduction of natural-ignition fire in the Bob Marshall Wilderness of Montana has restored low-density mixed conifer forest dominated by large, old ponderosa pine by consuming surface fuels and thinning shade-tolerant species from the forest understory and mid-canopy.[152]

These studies support the concept that repeated fires will move ponderosa pine and dry mixed-conifer systems towards predominantly low-severity fire equilibrium, consistent with the body of work focused on frequent fire systems achieving a self-regulating state.[153] The consistent theme is that a mixed-severity initial fire entry creates conditions conducive to repeat burning at low and moderate severities within the historical fire regime.[154] By allowing for moderate sized patches of high mortality that do not generally exceed 100 to 200 hectares (where determined appropriate by optimization analysis), there is relatively little risk of high-severity re-burning, inadequate regeneration, excessive coarse woody debris loadings, or transition to non-forest types.

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[148] Huffman *et al*. 2017b. Restoration benefits of re-entry with resource objective wildfire on a ponderosa pine landscape in northern Arizona, USA. *Forest Ecology and Management* 408: 16-24.

[149] pp. 526-527 in Collins and Stephens 2007. Managing natural wildfires in Sierra Nevada wilderness areas. *Frontiers in Ecology and the Environment* 5(10): 523–527.

[150] p. 10 in Collins *et al*. 2011. Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. *Ecosphere* 2(4): 1-14.

[151] Taylor 2010. Fire disturbance and forest structure in an old-growth Pinus ponderosa forest, southern Cascades, USA. *Journal of Vegetation Science* 21: 561-570.

[152] Larson *et al*. 2013. Latent resilience in ponderosa pine forest: effects of resumed frequent fire. *Ecological Applications* 23(6): 1243–1249.

[153] Miller and Aplet 2015. Progress in Wilderness Fire Science: Embracing Complexity. *Journal of Forestry* 113: 1-11; and Parks *et al.* 2014; Parks *et al.* 2015

[154] Laughlin and Fule 2006. Meeting forest ecosystem objectives with wildland fire use. *Fire Management Today* 66(4): 21-24.

## IV. THE STRATEGIC TREATMENTS FOR FIRE USE ALTERNATIVE FRAMEWORK

USFS research scientists have long worked to develop decision support, risk management, and prioritization tools for use in applications like 4FRI. Their work has been fundamental in establishing the science of optimization that is increasingly being explored and implemented in the western United States. Important considerations for utilizing wildland fire use have been identified by fire management professionals[155] and agency-developed risk management and decision support systems, such as Fire Effects Planning Framework,[156] provide systematic geospatial techniques for managing fire for resource benefit.

Ager and colleagues stated in a 2013 article that "*Meeting the long-term goals of dry forest restoration will require dramatic increases in prescribed and managed fire that burn under conditions that pose minimal ecological and social risk. Optimization models can facilitate the attainment of these goals by prioritizing management activities and identifying investment tradeoffs.*"[157] That 2013 work, located in ponderosa pine forests on the Deschutes National Forest in Oregon, studied an optimization model "…*to locate project areas to most efficiently reduce potential wildfire loss of fire resilient old growth ponderosa pine while creating contiguous areas within which prescribed and managed fire can be effectively used...*"[158] The complex modelling and algorithms used by the researchers ultimately identified locations where strategically deployed mechanical treatments would reduce flame length and thus save old growth ponderosa pine.

One common fundamental similarity between all optimization models is that they seek to reduce fire-severity or minimize wildfire risk, balancing tradeoffs between the size of treatment units, the placement of treatments, and the proportion of the landscape treated.[159] Collins and colleagues[160] also reviewed fuel treatment strategies, including much of Finney and Ager's work, and arrived at some basic parameters for optimizing fuel reduction treatments at the landscape scale that provide some guidance for those evaluating tradeoffs and can be used as guidelines in the *Strategic Treatments for Fire Use Alternative*:

> • Treating 10% of the landscape provides notable reductions in modeled fire size, flame length, and spread rate across the landscape relative to untreated scenarios, but treating 20% provides the most consistent reductions in modeled fire size and behavior across multiple landscapes and scenarios.
>
> • Increasing the proportion of area treated generally resulted in further reduction in fire size and behavior, however, the rate of reduction diminishes more rapidly beyond 20% of the landscape treated.

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[155] Black *et al.* 2008. Wildland Fire Use Barriers and Facilitators. *Fire Management Today* 68(1): 10-14.
Doane *et al.* 2006
[156] Black and Opperman 2005. Fire Effects Planning Framework: a user's guide. RMRS-GTR-163.
[157] p. 11 in Ager *et al.* 2013
[158] p. 3 in Ager *et al.* 2013
[159] Collins *et al.* 2010. Challenges and approaches in planning fuel treatments across fire-excluded forested landscapes. *Journal of Forestry* Jan/Feb 2010: 24-31
Chung 2015. Optimizing fuel treatments to reduce wildland fire risk. *Current Forestry Reports* 1: 44-51.
Krofcheck *et al*. 2017a
[160] Collins *et al.* 2010

> • Random placement of treatments requires substantially greater proportions of the landscape treated compared with optimized or regular treatment placement.
>
> • The improvements offered by optimized treatments are reduced when 40-50% of the landscape is unavailable for treatment due to land management constraints.
>
> • Treatment rates beyond 2% of the landscape per year yield little added benefit.

Considering the fire modeling already underway by the USFS, and the key takeaways reviewed here, the Center believes that a modified version of the methodology developed by the Hurteau lab and used by Krofcheck and colleagues[161] is most appropriate for the Rim Country analysis. Their optimization model, which mechanically treats only the operable areas with a high probability of mixed- and high-severity fire, was shown in multiple fire simulations to be as effective as thinning all operable acres at reducing wildfire burn severity and facilitating landscape scale low-severity fire restoration. The authors summarize their methods here:

> "*We developed three scenarios: no-management, naive placement, and optimized placement. Both management scenarios employed combinations of mechanical thinning and prescribed burning. The naive placement scenario aimed to simulate mechanical thinning from below and prescribed fire to all forest types that have experienced a fuels load departure from their historic condition due to fire exclusion. Within each forest type that received mechanical thinning, thinning was constrained based on operational limits (slope>30%, which totaled 22,436 ha available for mechanical thinning). The optimized placement scenario further constrained the area that received mechanical thinning by limiting thinning to areas that also had a high probability of mixed- and high-severity wildfire…In both treatment scenarios, stands identified for mechanical treatment were thinned from below, removing roughly one-third of the live tree biomass over the first decade of the simulation. Stands selected for mechanical thinning were only thinned once in the simulations, and all thinning was completed within the first decade*."[162]

Their results suggested that thinning the most optimum 33% of the operable acres could achieve the same effect as thinning all operable acres. The study was simulated in the Sierra Nevada of California, but the authors asserted that their approach was *"broadly applicable to historically frequent-fire ecosystems, or systems which have transitioned away from a low severity and fuel limited fire regime to one characterized by high-severity fires*."[163] The authors have recently completed similar optimization simulations in the Santa Fe Fireshed, which is likely to provide additional direction for utilizing such an approach in Southwestern ponderosa pine and mixed conifer forests (findings are to be published in summer, 2018).[164] We believe that it is possible and beneficial to integrate the existing 4FRI fire behavior and risk assessment modelling into an optimization simulation based on that work. We recommend that the Hurteau Lab is contacted immediately to begin dialogue with 4FRI Stakeholders as to how an optimization process can take existing fire modelling to the next level of strategic utility, while

[161] Krofcheck *et al*. 2017a; Krofcheck *et al*. 2017b
[162] p. 2 in Krofcheck *et al*. 2017a
[163] p. 6 in Krofcheck *et al*. 2017a
[164] Personal communication: Matt Hurteau, University of New Mexico, March 29, 2018

maintaining the viability of existing consensus agreements for treatments in SPLYT stands, old and large tree retention, Mexican spotted owl and northern goshawk habitat, and aquatic ecosystems.

**Three-tier Management Area Strategy**

Reflecting advances in landscape level planning, the *Strategic Treatments for Fire Use Alternative* proposes a three-tier strategy, basing management area decisions on optimized treatment locations rather than just arbitrary distances from values-at-risk. Past management zone strategies have been proposed by fire ecologists to facilitate resource benefit fire in Wilderness areas, and were based on distance from the wildland-urban interface.[165] Later, those approaches were extended to non-Wilderness public lands beyond a 5 ½ mile buffer around private land.[166] Both of those distance-dependent approaches resulted in identification of community protection zones, restoration management zones, and fire use zones. More recently, USFS and academic scientists called for a similar three-zone approach to be incorporated into National Forest Land and Resource Management Plans, with no specification of zone distances from the wildland-urban interface.[167] Conversely, the *Strategic Treatments for Fire Use Alternative* proposes that thinning treatments be prioritized in the Wildland Urban Interface, around critical infrastructure, and in areas having the highest probability of active crown fire, irrespective of proximity to human values-at-risk. Placement of such treatments would reflect existing 4FRI protections (SPLYT, MSO, etc) as well as economic costs/benefits of implementation. The three tiers of the Alternative are as follows:

*Tier 1) Community Protection.* These areas should be highest priorities for mechanical treatment, where feasible. Identification of the Community Protection Areas follows the consensus-based criteria established in the first 4FRI EIS of ½ mile around homes and critical infrastructure. Consistent with the agreements forged in the *Analysis of Small-Diameter Wood Supply in Northern Arizona* and memorialized in the first EIS, management objectives for the Community Protection Areas take precedence wherever they overlap with another management area. Extended Duration Restoration treatments, as proposed in the modified Alternative 2, may be appropriate for experimental implementation in this zone within a research framework. Additional areas that demand special attention may be addressed through the collaborative stakeholder process.

*Tier 2) Strategic Thinning Treatment.* These areas should be the next level of priority for mechanical treatment, implementing consensus-based treatments already agreed-upon by the USFS and the 4FRI Stakeholders. The Flexible Toolbox Approach, once agreement is reached on its parameters and constraints, could be utilized in these areas with the additional option of treating with fire-only if stand conditions permit, if mechanical treatment is not economically viable, and/or if on the ground conditions differ from expectations. *Strategic Thinning Treatment* areas would be identified through optimization analysis. An additional, secondary prioritization could be developed collaboratively to identify those stands which are the foremost priority for accelerated mechanical treatment within this zone. This analysis should include all "other projects" within the Rim Country footprint, because "*Understanding where past fuel treatments and wildfires have occurred is important for prioritizing future fuel*

[165] Wilmer and Aplet 2005. Managing the Landscape for Fire: A Three-Zone, Landscape-Scale Fire Management Strategy. The Wilderness Society, Washington, DC.
[166] Aplet and Wilmer 2010. The potential for restoring fire-adapted ecosystems: exploring opportunities to expand the use of wildfire as a natural change agent. *Fire Management Today* 70(10): 35-39.
[167] North *et al.* 2015b

*treatment.*"[168] Based on the 2010 synopsis competed by Collins and colleagues, a reasonable starting point may be that approximately 20% of the operable landscape could be targeted for strategically placed treatments, which would equate to approximately 250,000 acres of the Rim Country footprint. Krofcheck and colleagues optimization simulations from the Sierra Nevada resulted in approximately 8.5% of the landscape being identified for mechanical treatment. It will be important to let the process speak for itself, but if the optimization successfully locates thinning treatment priorities within those ranges, that amount of available acreage would provide 15-20 years of contracts to local industry, especially considering the challenges to implementation discussed earlier in this document. These acres may be in addition to those within the *Community Protection* areas and would be determined through the optimization analysis.

*Tier 3) Fire Use.* Areas located outside Tier 1 and 2 are not prioritized for mechanical treatment. Instead, management prioritizes prescribed and resource benefit fire at frequencies appropriate to local fire regimes. Because progressively warmer and drier winters may be conducive to year-long prescribed fire,[169] we recommend that increased resources are made available for burning, including the use of Prescribed Fire Training Exchanges (TREX), Wildland Fire Modules, forming prescribed fire councils, and a dedicated 4FRI prescribed fire implementation team.[170]

## V. CONCLUSION

Optimizing spatial prioritization of mechanical treatments reflects an evolution of fire management, placing emphasis on restoring fire as a natural process, rather than simply disrupting fire spread and protecting areas from burning.[171] The result of a strategic approach is to move away from managing for short-term outcomes and towards achievement of long-term restoration goals and objectives, consistent with calls from the scientific community to increase the use of prescribed and managed wildfires for resource benefit.[172] In a review of optimization strategies, Collins and colleagues stated that "*The basic idea is that an informed deployment of treatment areas, a deployment that covers only part of the landscape, can modify fire behavior for the entire landscape.*"[173] As an example, researchers have observed that thinned stands within the Rodeo-Chediski Fire affected fire behavior in neighboring untreated stands, leading to more complex heterogeneity, reduced fire severity, and increased ponderosa pine regeneration following the fire.[174] The Center believes that an *informed deployment* of the mechanical and fire treatments can more effectively and efficiently restore ponderosa pine and mixed conifer forests of the Rim Country landscape than the current 4FRI direction, and the *Strategic Treatments for Fire Use Alternative* is the way to get there.

[168] p. 301 in Vaillant and Reinhardt 2017
[169] Seager *et al.* 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316:1181.
[170] Stephens *et al.* 2016
[171] Ager *et al.* 2013
[172] Stephens *et al.* 2016
[173] p. 25 in Collins *et al.* 2010
[174] Shive *et al.* 2013