Ponderosa Pine Ecosystem Resilience Metrics and Desired Conditions

DWRF's Vision: A resilient and adaptive upper Dolores River watershed that provides ecosystem services, maintains ecological integrity, and sustains community values in the face of environmental change, supported by a diverse and active collaborative group.

In this document we seek to build on this collaboratively-defined vision statement by articulating specific ecological trends and monitoring metrics that foster a more "resilient and adaptive" ponderosa pine zone within the DWRF landscape. The timescale for this document is one to two decades, but we acknowledge this may be unrealistic for certain desired conditions. Within the strategic plan, the collaborative highlights enhancing resistance, resilience, and adaptive capacity within the DWRF landscape for both social and ecological conditions (see below for the definitions used within the strategic plan). We further identify historical land management legacies (such as extensive logging in ponderosa pine) and climate change as challenges to sustaining diverse values across the landscape and managing for resilience.

A DWRF subgroup focusing on the ponderosa pine zone met throughout the spring, summer, and fall 2020. The group developed shared trends, monitoring metrics and associated desirable ecological conditions that incorporate social and economic considerations and realities. Outcomes of this process were to have an outward-facing document that articulates the shared values and vision of collaborative stakeholders, but one that also is a useful tool for stakeholders to use in their professions - ranging from project planning on federal and state lands to informing private landowner projects. Importantly, there was a strong desire to ensure that the trends and metrics were locally specific/informed and in line with extensive published information about ponderosa pine ecology, management, and restoration. The west side of the San Juan Mountains has a particular set of ecological conditions and legacies, and any desired condition must be directly applicable to this landscape. To do this, we brought a broad diversity of stakeholder values and perspectives to the discussions, incorporated relevant science, and utilized the experience, knowledge, and context from local resources managers.

When available and applicable, the group had a goal to inform desired conditions with local reconstructions of the historical range of variability (HRV) as well as possible/likely climate change-driven ecological trends. The HRV concept assumes that historical ecological systems had substantial resilience in structure and function to climatic fluctuations and natural disturbances. By extension, employing HRV concepts in management actions and goals may help confer resistance and resilience in contemporary ecological systems. There are a number of ponderosa pine stand (Brown and Wu 2005) and landscape reconstructions (Baker 2020) and syntheses (Romme et al. 2009, Baker 2018a) in San Juan ponderosa pine and many other HRV reconstructions throughout Colorado (Uncompahgre Plateau, Front Range), and northern Arizona and New Mexico. These reconstructions, particularly focusing on those in southwest Colorado, can help inform our current effort to articulate desired ecological and social conditions. Differences in soils, productivity, precipitation, and other factors may limit applicability in particular cases. Further, HRV data for southwest Colorado are focused on forest composition, structure, and fire frequency/severity and generally do not give context to other important ecological conditions, such as historical forb and grass composition, insect disturbance, etc.

Additionally, while HRV is an essential context, climate change, social factors, ecological/management legacies, and current forest conditions (such as a large-scale beetle outbreak) require additional contexts. For example, future range of variability (FRV), informed by a hotter/drier climate and associated changes in disturbances, may be an equally appropriate lens, but there is considerable uncertainty about what future climatic conditions mean on the ground. How climate change impacts will influence desired conditions, for instance in the context of leading/trailing edges, remains an important knowledge gap that the group prioritizes for additional context and information. In summary, DWRF highlights resistant, resilient, and adaptive forests, informed but not constrained by both historical and future variability, as in other frameworks (e.g. Addington et al. 2018).

This is an aspirational document, and the collaborative acknowledges that diverse ownerships and land uses shape what is feasible. The document helps ground the collaborative's engagement with adaptive monitoring and adaptive management planning and implementation. The collaborative acknowledges that, in some cases, the desired conditions may not be achievable within the stated timeframe, but they are still aspirational goals. While the collaborative articulates a series of desired conditions here, another important outcome of this document has been the identification of key gaps in its knowledge of the local ponderosa pine system. As more monitoring is conducted across the DWRF geography, as better ecological modeling tools become available, and as the larger body of knowledge is improved, the collaborative will periodically revisit this document to incorporate those advancements. Additionally, the collaborative acknowledges that desired conditions proximal to highly valued resources and assets (e.g. communities and infrastructure) may diverge and have different management goals from those outlined here. Outlining specific desired conditions near HVRAs is part of a larger effort of the collaborative, but is beyond the scope of this document. Lastly, changing social, economic, and ecological values for the stakeholders should and will be considered during the periodic reevaluation of these desired conditions.

<u>Principal stakeholders involved in developing and reviewing this document:</u>

- Danny Margoles, DWRF Coordinator
- Bill Baker, Retired Ecologist
- Jimbo Buickerood, San Juan Citizens Alliance
- Ryan Cox, Colorado State Forest Service
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- Mike Remke, Mountain Studies Institute and Fort Lewis College
- Bruce Short, Short Forestry LLC

Ponderosa pine					
	Desired Condition	**Ecosystem Parameter**	**Desired Trends**	**Indicator**	**Sources to Analyze Trends**
1	**Tree species composition that promotes ecological resilience**	Tree species	• Generally retain or restore historical species/ecotypes/genetic diversity as well as those associated with likely climate-related trends/movement[1] • Retain and enhance rare or uncommon species composition when feasible (e.g., aspen and aspen clones)	• Percent composition by species tree density • Tree density by species • Canopy cover by species when available • Abundance by species based on site index, basal area, and disturbance history	• GLO and other historical data • Modern CSE/MSI plots • Remote sensing
2	**Mosaic of forest understory shrub composition, density, and size that promotes ecological resilience.**	Shrub species	• Maintain or restore historically variable Gambel oak and other shrub density that also enables variable ponderosa pine regeneration, forb and grass abundance, and meets wildlife habitat needs[2] • Maintain or restore historical heterogeneity in size classes of Gambel oak, particularly maintaining larger diameter classes. • Maintain or restore historical diversity of shrub composition related to environmental setting, and to support wildlife needs.	• Presence, cover, abundance, and diversity of shrubs	• Historical accounts, GLO data, and other historical data • Modern understory plots

3	**Mosaic of forest understory grass and forb composition, density, and cover that promotes ecological resilience.**	Grass and forb species	• Promote and restore historically variable native grass and forb abundance and composition[2].	• Presence, cover, and diversity of native grasses and forbs	• Historical accounts, GLO data, and other historical data • Modern understory plots
4	**Mosaic of forest understory composition, density, and cover that has reduced noxious or invasive plants, promoting ecological resilience.**	Noxious or invasive plant species	• Decreased occurrence and cover of noxious/invasive plant species as listed on Colorado noxious weed species lists A, B and C • Post-treatment, maintain the appropriate native plant community to limit potential for establishment of noxious/invasive plant species	• Presence and cover of invasive species	• Understory plots; • Ground cover plots; • Weed inventory
5	**Stand scale - Complex mosaic of tree density and basal area that promotes ecological resilience**	Tree density and basal area	• Restore historically variable tree density and basal area[3-5] • Tree densities and basal areas vary with productivity, soils, and disturbance history[6]	• Basal area • Tree density • Canopy cover by species when available	• GLO data, historical accounts, and other historical data • Modern CSE/MSI plots

6	**Stand scale - Complex mosaic of tree sizes that promotes ecological resilience**	Tree sizes	● Restore historical heterogeneity in tree size classes, consistent with uneven-aged stand structures, including but not limited to reverse-J and multi-cohort management [7] ● Generally, increased seedlings and saplings, fewer medium-sized trees, and increased large trees, relative to today.	● Diameters at breast height for trees > 4.5 feet and height classes for seedlings	● GLO data and other historical data ● Modern CSE/MSI plots ● Remote sensing; ● LIDAR data
7	**Stand scale - Complex mosaic of tree ages and increased old growth that promotes ecological resilience**	Tree ages	● Restore historical age structures ● Restore and enhance rare components of stands that are essential for resilience to fire, particularly large and old trees, by retaining and increasing trees exhibiting old-tree characteristics[8] ● Increase old growth and move from predominantly single-aged to uneven-aged stands ● Promote younger age classes to advance into older classes	● Percentage of landscapes and forest area meeting old-growth criteria ● Diameter distribution charts ● Heterogeneity in age-class structure	● Historical GLO reconstruction of old growth and other historical data ● SJNF old-growth inventory ● Modern CSE/MSI plots
8	**Stand scale - Complex mosaic of snags and down wood that promotes ecological resilience**	Snags	● Retain > 1 snag per acre per species of suitable size for cavity nesters and other wildlife use, where appropriate (non-hazardous snags, away from HVRAs, etc.) and increase their representation on the landscape[9] ● Snag placement that maximizes wildlife benefit (e.g. adjacent to aspen stands, large openings, areas they are missing).	● Snag abundance	● Early historical photographs and other early records ● Modern snag Inventories

9	**Stand scale - Complex mosaic of forest floor conditions that promotes ecological resilience**	Forest floor	● Retain or restore historically congruent amounts of coarse woody debris on the forest floor[9] ● Undesirable condition – too little or too much coarse woody debris	● Coarse woody debris abundance	● Early historical photographs and other early records ● Modern coarse woody debris inventories
10	**Stand scale - Complex within-stand heterogeneity in forest density, size, and age that promotes ecological resilience**	Within-stand spatial heterogeneity	● Restore and maintain historical tree clumps and spatial heterogeneity (horizontal and vertical) of tree pattern[10] ● Spatial heterogeneity varies with productivity, soils, and disturbance history	● Proportion of stand represented in individual trees, clumps, and openings (ICO method[10])	● Historical GLO reconstructions, early reports, historical photographs, and other historical data ● Modern spatial pattern plots
11	**Landscape scale - Complex mosaic of forest density, size, and age that promotes ecological resilience**	Landscape patch sizes and structures	● Restore or maintain historically guided heterogeneity of patch sizes and structures across the landscape mosaic, including non-forested patches[11-12] ● Generally, more low- and high-density forest patches, more large patches, and more variability in patch sizes and structures to offset overly abundant moderate-size and moderate-density patches, relative to today[11-12]	● Heterogeneity of patch size and structure ● Heterogeneity of patches across seral/ structural stages	● Historical GLO landscape reconstructions, early forest atlases, and other historical data ● Modern remote sensing, using CFRI and other spatial analyses

12	**Landscape scale - Complex mosaic of forest density, size, and age that promotes ecological resilience**	Stand ages	• Restore and maintain historically guided abundance and variability of old-growth stands and scattered old trees across landscapes[8] • Restore and maintain historically guided abundance of conditions conducive to new ponderosa pine stand recruitment	• Relative abundance of old-growth stands and scattered large trees • Variability in the abundance of ponderosa pine stand regeneration	• Historical GLO reconstructions, early records, and other historical data • Modern CSE/MSI plots • SJNF Old-growth inventory
13	**Landscape scale - Complex mosaic of forest density, size, and age that promotes ecological resilience**	Habitat fragmentation	• Minimize impacts to corridors between patches to improve connectivity[13] • Minimize edge effects by minimizing the road network, and by promoting larger patch sizes with a lower proportion of edge[13]	• Landscape connectivity • Edge area, interior area vs. total landscape area • Species specific fragmentation effects	• Historical GLO and other historical data • Modern CPW, SJNF, MSI data • Modern Remote Sensing data • CFRI/MSI and other landscape analysis
14	**Insects and disease disturbances - Increase resistance and resilience to bark beetle outbreaks.**	Tree density Tree sizes	• Stand[14] and landscape[12] desired conditions generally match desired conditions for increasing resilience to bark beetle outbreaks • Overall, lower and more variable tree densities and basal areas to enhance resistance and resilience to bark beetles[12, 14] • Maintain and enhance genetic and structural diversity across the landscape, and by using variable uneven-aged management at the stand scale[12, 14, 15] • Enhance tree regeneration and recruitment for long-term resilience	• Beetle-caused tree mortality • Indicators for desired conditions 7, 10, 12	• Modern aerial detection surveys, MSI plots, CSE data, RMRS and CSFS plots

15	**Fire disturbance - Increase resistance and resilience to fires**	Tree density Tree sizes	• Restore and maintain historically guided rates, patterns, and variability of fires[16] • Generally, more low and moderate-severity fires	• Fire rotations • Fire-caused tree mortality • Indicators for desired conditions 7, 10, 12	• Historical GLO and other historical data • Modern USFS, BLM, and MTBS surveys, MSI plots, CSE data, other data

Glossary

Adaptive capacity: The capacity of social-ecological systems, including both their human and ecological components, to respond to, create, and shape variability and change in the state of the system (Chapin et al., 2010).

Future Range of Variability – The range of structures, compositions, and processes that characterizes ecological systems that are feasible under future land use and climatic change; in this case, used to predict potential resilience scenarios into the future.

Historical Range of Variability - The range of structures, compositions, and processes that characterized ecological systems before Euro-American settlement; often used to inform ecological restoration goals and objectives (Aplet and Keeton 1999; Keane et al. 2009). We use local information that includes stand-level reconstructions of forest structure as well as landscape-level reconstructions from General Land Office and other sources to estimate historical range of variability for our local region.

Landscape – visible features of an area of land that includes both its physical and biological elements (Puettmann et al. 2009); or, a spatial mosaic of several ecosystems, landforms, and plant communities across a defined area irrespective of ownership or other artificial boundaries, and repeated in similar form throughout (Helms 1998).

Old trees – Old trees have a DBH exceeding 18" and are 160 years old or older (Mehl 1992). To support field identification of old trees, trees should have three out these four characteristics: (1) DBH exceeding 18", (2) possess large branches, (3) have sprawling flat crowns, and (4) have deeply furrowed orange bark (adapted from Mehl 1992 and Brown 2018).

Resilience: The capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks (Walker et al., 2004).

Resistance: The ease or difficulty of a disturbance to change a system (Folke et al., 2004).

Restoration – Actively assisting the recovery of a system, that has been damaged, degraded, or destroyed, to a more resilient state (modified from SER 2004). Our definition uses historical range of variability (HRV) as a proxy or guide for resilient conditions, assuming historical forest structures were resilient to a variety of disturbances. While HRV is an essential guide, multiple future constraints (e.g., climate change, land-use change) mean that FRV must also be considered in formulating restoration goals.

Sapling – A tree that is in its present form more than 4.5 ft tall but has a diameter that is less than 5 inches

Seedling – A young tree that is in its present form less than 4.5 ft tall.

Stand – a contiguous group of trees sufficiently uniform in age-class distribution, composition, and other aspects of structure, and growing on a site of sufficiently uniform quality, to be a distinguishable unit (Helms 1998).

Stand-scale – a scale on the order of up to about a few hundred acres.

Tree - any woody vegetation with one to a few dominant stems that is, or could potentially be, > 4.5 ft tall, and a DBH > 5 inches

Notes

1. See papers describing climate-related trends, leading and trailing edges, and post-fire regeneration related to climate change (e.g., Shinneman et al. 2016, Parks et al. 2019, Greiser et al. 2020, Rodman et al. 2020).
2. Romme et al. (2009 p. 37-38) and Baker (2020 p. 16-18) provide evidence about the historical variability of understory shrub vegetation. Romme et al. (2009 p. 37) and Paulson and Baker (2006 p. 181-184, 193, 200-211) provide evidence about historical variability in understory forbs and grasses.
3. Reconstructions and historical data suggest basal areas and stand densities were lower and more variable than in current forests.
    - Basal Area
        - i. Historical GLO data suggest significant variability in basal area across the San Juan Mtn ponderosa pine zone, but averaging 50 ft^2/acre (Baker 2020 Table 7)
        - ii. Historical data and reconstructions on the Uncompahgre Plateau similarly demonstrate variability across the landscape, averaging 55 ft^2/acre (Binkley et al. 2008) and 45 ft^2/acre (Baker 2017).
        - iii. Wasserman et al. (2019) reviews HRV for tree density and basal area for other areas of the Southwest.
    - Tree Density
        - i. Romme et al. (2009 p. 38-40) made historical estimates from extant old trees and stumps that suggest substantially lower density historically than today. The three sites they reconstructed in the DWRF landscape - Smoothing Iron, Plateau Creek, and Five Pine Canyon - average 15, 17, and 20 trees/acre respectively. These are underestimates of overall tree density since, as Romme et al. explain, smaller stumps likely have disappeared.
        - ii. Baker (2020 Table 6) reconstructed tree density for 93 sample polygons across the southwestern San Juan pine zones, with most estimates from the DWRF area. Mean historical tree density for trees > 4" at stump height was 67 trees/acre and the median was 43 trees/acre, with a large variability in density.
        - iii. Historical data and reconstructions on the Uncompahgre Plateau similarly demonstrate variability across the landscape, averaging 55 trees/acre (Binkley et al. 2008) and 68 trees/acre (Baker 2017).
        - iv. Wasserman et al. (2019) reviews HRV for tree density and basal area for other areas of the Southwest.
4. Restored tree density and basal area promote drought resistance and enhance growth rates for trees of all sizes, and restoring historical tree density and basal area using fire and mechanical methods can help achieve these conditions (e.g. Kolb et al. 2016, Stephens et al. 2020). However, slower-growing trees are more resistant to mortality in intense beetle outbreaks in ponderosa pine (de la Mata 2017), and resilience after mortality from drought and beetle outbreaks is typically from smaller trees and more resistant slower growing larger trees, which often survive beetle outbreaks at a higher rate, and are essential sources of natural recovery (de la Mata et al. 2017, Baker 2018b).
5. See 2.2.1 in *Volume II: Final San Juan National Forest and Proposed Tres Rios Field Office Land and Resource Management Plan* (LRMP) for management direction reference on SJNF lands.
6. Productivity definition from Helms (1998): "Productivity is defined in an ecological context as "the rate at which biomass is produced per unit area by any class of organisms." Note that productivity refers to a rate of biomass production, so it reflects a site's intrinsic capability to grow trees"
7. Baker (2018b) and Bryant et al. (2019) identify that resilience to various disturbances (i.e. drought, fire, insects) is likely best created by heterogeneity in:

- Tree genetics (Fischer et al. 2010, Six et al. 2014, Kolb et al. 2016)
- Diversity in tree age and size, density, and basal area (Baker and Williams 2015)
- Natural disturbances (Baker 2018b)

8. Tree sizes, old-growth forests and old-tree characteristics
    - Baker (2020 Figure 8) presented historical size-class distributions from bearing trees directly recorded by GLO surveyors. Baker (2020 Table 9) shows the percentage of GLO bearing trees that exceeded particular diameters, which provides reference information about variability in tree sizes.
    - Romme et al. (2009 p. 44-45) presented age and size-class distributions for remnant old-growth forests, and Romme et al. (1992) provided an overview of the ecological importance of old-growth forests in the San Juan Mountains.
    - Baker (2020 p. 21-26, Table 14 and Figures 12 and 13) presented reconstructions from GLO section-corner and section-line data that show that about 59% of reconstructed historical ponderosa pine forests and 26% of the historical ponderosa pine zone would have met criteria for old growth.
    - See R2FSVeg Spatial Tool Overview p. 12-13 for the Region 2 old-growth definitions used on the SJNF, see Mehl (1992) for general scientific old-growth definitions, and 2.2.1 in the LRMP for management direction on SJNF lands.
    - SJNF digital old-growth atlas is in FSVegSpatial, NRIS_VegPolyLocalCalcs, available from the SJNF GIS coordinator.
    - See Keen age and vigor class descriptions (1936 and 1943)
    - See Brown et al. (2019) for a more nuanced approach to identifying old trees. Based on local resource specialists, there may be a propensity to misidentify some young trees as old based on just size criteria.
    - Water-limited trees may also present old-tree characteristics without being particularly old themselves.
9. Snags and down wood
    - Romme et al. (2009 p. 40-41 and 45-47) and Paulson and Baker (2006 p. 194-195) explain the historical importance of snags and down wood in ponderosa pine forests on the SJNF. Romme et al. explain that there remains considerable uncertainty about the historical abundance of snags and down wood in DWRF ponderosa pine forests, but the ecological values of snags and down wood are clear.
    - Brown et al. (2003) suggest 5-20 tons/acre as an optimal quantity to provide for a range of ecological needs while balancing with fire hazard.
10. Within-stand spatial heterogeneity
    - Baker (2020) found that only the lower 15-24% of the montane zone in the DWRF area historically had generally low tree density, large trees, and relatively frequent fire that particularly promoted classical within-stand heterogeneity in forest structure, but this heterogeneity could also have occurred in some other areas.
    - Romme et al. (2009 p. 39-41) presented evidence that pre-1900 trees in these parts of the DWRF area had a diversity of clump sizes
    - Key reviews of within-stand heterogeneity in ponderosa pine forests are Larson and Churchill (2012) and Churchill et al. (2013).
    - Reynolds et al. (2013 GTR-310) provided similar descriptions of interspaces and openings in old southwestern ponderosa pine forests. Interspaces are areas not under the vertical projection of the outermost perimeter of tree canopies. They are generally composed of grass-forb-shrub communities but also scattered rock or exposed mineral soil. Interspaces do not include meadows,

grasslands, rock outcrops, or wetlands adjacent to, and sometimes within forest landscapes. Interspaces are areas that could, in the future, support tree regeneration.
    - Tuten et al. (2015) provided details about measuring and restoring within-stand heterogeneity in ponderosa pine in the Southwest.

11. Historical landscape variability in tree density, but not in basal area, was higher in DWRF ponderosa pine forests than in similar forests in northern Arizona
    - Baker (2020) found that ponderosa pine forests in the DWRF area were similar to ponderosa pine forests in northern Arizona in median tree density and basal area, but variation in tree density across the landscape was about twice as high, likely due to more topographic diversity and historical variability in fire in the DWRF area.
    - Baker (2020) found that the DWRF area had more open, low density forests and also more dense and very dense forests than in northern Arizona, another indication of more landscape variability in tree density in the DWRF area.
    - Baker (2020) found there was little difference in variability in basal area across DWRF and northern Arizona landscapes.
12. Resistance and resilience to drought, insect outbreaks, and fire are likely enhanced by heterogeneity in tree density and basal area across a ponderosa pine landscape
    - Variability in tree density, basal area, and composition across landscapes likely provides resistance and resilience to disturbances by reducing the uniformity of vulnerability to disturbances and slowing the physical and biological spread of disturbances, thus increasing opportunities for some trees to survive; survivors begin natural recovery and subsequently provide essential seed that furthers recovery and thus resilience after disturbances (e.g., Turner et al. 1989, Graham et al. 2016, Seidl et al. 2018).
13. Forest fragmentation—corridors, edge area, interior area
    - Analysis of these three components of forest fragmentation in the Southern Rocky Mountains is in Knight et al. (2000).
    - Detailed analysis of fragmentation by logging and roads in the San Juan Mountains (McGarigal et al. 2001 p. 327) found: “Roughly half of the mature coniferous forest was converted to young stands; mean patch size and core area declined by 40% and 25%, respectively, and contrast-weighted edge density increased 2- to 3-fold. Overall, roads had a greater impact on landscape structure than logging in our study area. Indeed, the 3-fold increase in road density between 1950–1993 accounted for most of the changes in landscape configuration associated with mean patch size, edge density, and core area.”
14. Negron et al. (2000) observed two factors that heightened the probability of roundheaded pine beetle infestation in ponderosa pine.
    - Basal area - stands with basal area (BA) >105 ft^2/acre had higher probabilities of infestation. Particularly, stands with BA <73.5 ft^2/acre had lower mortality rates. Baker (2020) found that > ¾ of historical ponderosa pine stands had BA <73.5 ft^2/acre.
    - Stands with slow growth rates in the past five years (periodic annual growth increments that are <0.26 inches/year) had higher probabilities of infestation. Stands with slowed growth rates were likely responding to a stressor like drought.
15. Genetic diversity can favor trees that are resilient to diverse disturbances, include drought and beetle mortality (Negron et al. 2000 and 2009; Fischer et al. 2010). Additionally, trees that survive outbreaks may be trees that possess traits that are resistant to beetle attack; however, knowing which trees will survive prior to an attack can be difficult (Six et al. 2018).
16. Primary sources of historical fire-history evidence (rates, patterns, and variability) include fire-scar reconstructions (compiled in Baker 2018a), forest age structure (e.g., Brown and Wu 2005), GLO reconstructions (Baker 2020), and early forest atlases, reports, and

newspaper articles (Baker 2018a). Modern data are primarily from records, reports, and mapping by the San Juan National Forest, the Bureau of Land Management, the Monitoring Trends in Burn Severity (MTBS) program, and miscellaneous other government programs.

- Historical low-severity fire burned with a mean rotation of 34 years, a median of 31 years, and a range of 16-59 years (Baker 2018a), and about 32% of the ponderosa pine zones had exclusive low-severity fire over the century prior to about 1880 (Baker 2020)
- Historical high-severity fire was very infrequent, with a fire rotation of 280 years, but evidence of high-severity fire in the century prior to about 1880 was found over 33% of ponderosa pine zones (Baker 2020). Moderate-severity fires were also infrequent and found over 35% of ponderosa pine zones (Baker 2020). The historical fire regime was mixed in severity with low severity predominant.
- Historical fire sizes can be only roughly estimated, but could possibly have rarely exceeded 125,000 acres overall, although with only some of this area in ponderosa pine zones (Baker 2018a).

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