Tahoe Science Advisory Council
Independent Peer Review
Tahoe Regional Planning Agency Forest Health Thresholds

Background

The Tahoe Regional Planning Agency (TRPA), in partnership with members of the Environmental Improvement Program and the Tahoe Science Advisory Council (Council), is updating its Forest Health Thresholds to reflect the latest scientific understanding of desired forest conditions in the Lake Tahoe Basin. The thresholds are designed to measure progress toward resilient forest ecosystems that can withstand disturbance, support biodiversity, and reduce the risk of large, high-severity wildfires. These thresholds are a core component of TRPA's environmental standards and guide basin-wide management and monitoring decisions.

As part of this process, TRPA developed draft desired condition targets based on forest structure, composition, and disturbance characteristics. These targets aim to guide management actions toward a more resilient forest ecosystems and the services that they support.

To provide an independent evaluation of the scientific basis and credibility of the draft thresholds, the TRPA requested that the Council conduct an independent third-party review.

Reviewers

The review was conducted by:

Patricia N. Manley, Ph.D.
Research Ecologist
U.S. Forest Service Pacific Southwest Research Station

Hugh D. Safford, Ph.D.
Research Ecologist
University of California, Davis

Review Charge

TRPA and the Council conducted the review with the objective of evaluating the scientific foundation, clarity, and practical applicability of the proposed forest health thresholds. Reviewers were given draft material, asked a series of targeted questions, and offered the opportunity to provide additional suggestions to improve the proposed threshold targets and clarify desired condition targets. TRPA met directly with each reviewer to discuss findings and explore opportunities to enhance the proposed threshold standards to align with other relevant efforts and ensure scientific rigor.

Review Findings and Recommendations

Both reviewers answered the charge questions and offered additional comments and suggestions to enhance the proposed threshold standards. Their unedited reviews are attached for reference.

Review Questions and Summarized Answers

1. **Scientific Foundation of Desired Condition Targets**
   a. *Are the proposed thresholds consistent with current science and best practices in forest ecology and management?*

   The reviewers found proposed thresholds to be generally consistent with current science/best practices in forest ecology and management and agree the identified metrics are key elements of forest health. Both Drs. Manley and Safford offered suggestions for improvement and raised additional questions about the ability to set targets and track other ecosystem benefits related to forest condition.

   Specifically, Dr. Manley noted the importance of considering forest extent, forest type, plant species composition, old forest quality, biodiversity, carbon storage and sequestration, and high value resources as all valuable ecosystem services that may not be adequately captured in the proposed forest threshold standards. Dr. Manley also made a series of detailed points regarding the proposed wildfire standards to help TRPA refine how the information is presented and justified and highlighted the concept of fire frequency is not considered in the current proposal. She noted that using a small patch size maximum for high severity fire may not be realistic or defensible and offered alternatives.

   Drs Safford and Manley both suggested TRPA consider Relative Stand Density Index as a useful metric of forest change over time.

   b. *Are the selected metrics (e.g., basal area, trees per acre, seral stage, canopy cover) well justified by the supporting rationale?*

   The reviewers found the selected forest composition metrics to be important and valuable. Dr. Safford noted the selected metrics are widely used and provide a common language among foresters worldwide. The chosen metrics are easily measured and described, and science has shown that they are important drivers of ecological composition, structure, and function. Dr. Manley commented that the specificity of acreage outcomes for seral stage and canopy cover by vegetation type may exceed the strength of the scientific foundation. Dr. Manley also identified several areas where the proposed WUI fire standards would benefit from additional justification and rationale.

   c. *Are there any gaps, limitations, or improvements that should be considered based on data that is readily available today?*

The reviewers identified several opportunities for TRPA to consider that could be supported by available data. Both reviewers noted the proposal did not include metrics that would track or incentivize change in the amount of various vegetation types. Dr. Safford again suggested TRPA could develop a threshold based on Relative Stand Density Index (RSDI) to provide a more responsive metric to forest condition. Dr. Manley reiterated the proposal's lack of metrics that capture numerous forest and fire conditions, such as overall seral stage and canopy cover thresholds, old forest quality, and fire as a process. Dr. Manley also encouraged TRPA to consider incorporating the California Wildlife Habitat Relationship system to connect forest condition to habitat suitability.

d. *How can the standards be structured to remain adaptable as new or improved data become available?*

Both reviewers noted the fundamental importance of periodic threshold review and update. As monitoring and data analysis methods improve, using remotely sensed data to compare change over time can be challenging. Both noted the value and importance of a comprehensive monitoring program to track the suite of forest health and related thresholds.

Drs. Safford and Manley note the importance of leveraging on-the-ground monitoring techniques whenever possible and offer ideas for data continuity. Both mention the difficulties that can arise when new, higher resolution data is compared with older information. TRPA should describe processes for addressing this issue, such as monitoring method overlap and calibrating remotely sensed data with empirical measurements.

2. **Applicability and Interpretability**

a. *Are the thresholds measurable, feasible to implement, and suitable for long-term monitoring and adaptive management?*

Generally, the reviewers found that because the proposed threshold standards are based on common metrics of forest and fire conditions, they are relatively easy to measure. Dr. Manley noted that standards for high severity fire patch size and old forest quality are likely exceptions. (if it were adopted).

b. *Are the thresholds clearly defined and easily interpretable for managers, policymakers, and the public?*

Drs. Safford and Manley agree the proposed threshold standards are well defined and can be reasonably understood by engaged stakeholders. Dr. Safford mentioned that managing basing forest management on seral stages for identified forest types could be difficult and again recommends considering a stand density index threshold. Throughout her review, Dr. Manley provides many suggestions for improving the documentation and structure to more clearly describe the system.

c. *Do the targets adequately account for climate change, fire regimes, and other key stressors?*

While the proposed targets incorporate anticipated dryer and warmer conditions, Dr. Safford again encourages TRPA to use stand density index as a measure that would more readily reflect drought, fire, insects, and other tree mortality agents.

Consistent with other comments, Dr. Manley again notes that the proposed threshold metrics do not explicitly account for change in tree species and vegetation type distribution. The distribution of various tree species is expected to shift in response to climate change, with the most significant changes occurring a lower elevation and the drier, east side of the basin.

Appendix 1 – Complete Review Comments

Pat Manley Review

Tahoe Science Advisory Council Forest Threshold Review
January 5, 2026

1. **Are the proposed thresholds consistent with current science and best practices in forest ecology and management?**

One overarching comment is that the document would benefit from adding a section – between outlook and data – that addresses what future 'management' inputs are available and what they can accomplish in general terms. Its title might be something like "Defining Management". The historical section provides a great overview of the past intentional management and its objectives, and the outlook provides an overview of the anticipated influence of climate. This new section would set the stage for the role of management going forward, and the types of management tools that are expected to be available for use. This is important because meeting and maintaining all of these standards will require 'management' to serve as an intentional disturbance function toward particular outcomes. The management tools – what do they include – mechanical removal, hand-treatment, fire, exclusion of disturbance (including human disturbance) – and what are they intended to accomplish – change structure or composition, reduce risk of high intensity disturbance, reduced impact of human disturbance. In some cases, management is intended to achieve a direct outcome (e.g., reduce fuels) and in other cases to affect a change in other disturbance functions (e.g., fire, beetles) or both. This section can then serve as a foundation for the intention of management for each threshold.

Forest Composition

The forest health thresholds address four main topic areas: forest composition and age, stand density, WUI wildfire protection, and landscape fire dynamics. These are key elements of forest health. Related elements, such as the ecosystem benefits or services or functions that healthy forests provide, are also important, some of which are addressed in other threshold standards, but many of which are not and would strengthen the document and its scientific merit to address them as part of the threshold. They are outlined below.

Forest extent - A simple but important threshold that appears to be missing is how much of the basin is forest? It is easy to take this for granted, but as we know, it is always changing, and can change quickly in response to major disturbance events through loss followed by the inability to restore forests. I suggest that some range of forested lands be established, probably based on the reasonable assumption that we have a high amount of forested lands at the current time due to lack of fire (although Caldor was somewhat of a correction factor). The low end of the range is simply a choice, but reasonable to assume people expect the basin to be forested and other than fire risk, it offers many ecosystem benefits.

Forest type composition – The forest types that occur in the basin today will change over time. Shifts in the amount and distribution of the dominant types will probably be measurable in the next 20 years as a function of management and climate. For example, the proposed changes in thresholds and the conditions they will create across the basin could result in less white fir and more pine dominated forests through the effects of more area of open canopy. An overarching threshold of forest diversity might be valuable, but setting a threshold for that would be challenging. I suggest noting that the diversity of forest types matters, that it will change, that tree species and forest types that are more robust to precipitation extremes, particularly drought, are likely to become more prevalent across the basin, and those that are adapted to persistent snowpack and more mesic conditions are likely to become less prevalent. Establishing a performance measure that tracks forest type amount and distribution would be valuable and serve as an early indicator that expected outcomes from current threshold standards that are summed across forest types (e.g., how many acres are in and out of attainment based on how they add up across forest types) will probably need to be adjusted over time.

Plant species composition - Tree species composition will change over time as a function of climate and management, and tree species composition has a substantial effect on understory plant species composition and cover, as well as stand complexity and habitat value. Forest plant composition is an element of biodiversity (see below), but I suggest that it should be included in the forest health threshold standard (or at least as a performance measure). Diversity of understory conditions could be represented simply as diversity of understory plant cover – herbs, shrubs, and shrub species diversity. Again, this may fall into the category of a performance measure given that setting anything other a threshold of some measure of diversity would be challenging.

Old forest quality/integrity - Old forests or late seral forest conditions are particularly important because they take a long time to form and replace if lost. Similarly, old forest 'legacy' elements, such as very large trees, snags and logs, place an outsized role in contributing to a range of forest functions and forest ecosystem diversity. This is a critically important aspect of forest ecosystem diversity and integrity and should be represented in some manner in the threshold standards. Old forests have a range of unique features, commonly including density of large trees, snags, and down logs, vertical diversity of vegetation, horizontal heterogeneity at various scales, diversity of understory plant species, and abundance and diversity of lichen and other non-vascular plants and associates. These are all measures of 'integrity' that are not limited to late seral forests, but late seral forest values are based on an expectation that they have high integrity.

Biodiversity - Biodiversity is an important component, contributor, and emergent property of healthy forests. Biodiversity is addressed as a stand-alone threshold standard. It will be important for the biodiversity threshold standard to be tailored to major ecotypes, with forests being one of those major ecotypes. Biodiversity measures and outcomes need to include at a minimum plants and vertebrates.

Carbon - Carbon storage and sequestration is another important ecosystem service that forests support, although other ecotypes are also important contributors (e.g., meadows). Carbon is an important ecosystem feature that has stand-alone merit, but it also provides a reliable and sensitive measure forest stability. Turnover in carbon (rapid loss followed by rapid gains) typically represents a loss of older forest and a successional reset. High turnover in carbon can be interpreted as a hazardous condition for forest persistence and emissions (air quality). Stable carbon is more ecologically beneficial (other than implications of fuels).

High value resources - High value natural resources are not mentioned as a factor in forest health, but they contribute to landscape resilience and forest health by extension. High value resources are important to identify, map and manage for them in the course of addressing objectives of stand density, landscape fire, and climate resilience, so that they are not invisible in the planning process and impacted or lost in the process of implementation.

Functional Fire in WUI

A few key points are noted below.

- The WUI area designation is not discussed – how wide are each of the two zones? How much forest (and % of all forests) are in each of the zones? The text is not entirely clear about if the acres being reported are forest or all acres, and whether or not the percentages apply to the entire area or to the forested area within each zone.
- I would think that the flame length targets would apply to all vegetation types, not just forest, so that should be clear to the reader. If it pertains to all vegetation types, then the proportion of the WUI in each veg type and then the percentage of each that is vulnerable to higher flame lengths reported. This will clarify the degree to which this standard is a likely to impact forests and how of the basin's forest.
- What is the basis for the 90% target? Generally, 4 ft flame length is reasonable in the defense zone, but not 90% of the threat zone, since it typically occupies such a large area.
- One acre patch size is very ambitious, even just within the defense zone. Nearly impossible (and not necessary) across the threat zone.
- An analysis of the impacts of this standard on the threat zone forests would be important, particularly to establish the degree to which there is any conflict between this threshold standard and target conditions for forest structure.
- Table 7 shows general forest and wilderness as "vulnerable" where flame lengths exceed 4 ft, but they are not included as part of the threshold standard – it is misleading. Suggested option is to retitle the column to read "Percent of zone with >4ft flames predicted", which allows the reader to see that they are pretty equivalent across the zones without statements of vulnerability.
- Figure 3 – is that just forest or all vegetation types or all land types (vegetated and non-vegetated)? Assuming the % are the proportion of the 200,984 acres? Just need to expand the caption to clarify. Also need to explain how the 200,984 was derived and what it represents.
- Figures 3 and 4 are not referenced in the text. Also there is no definition of moderate, although can get there through deduction.. best to state clearly how they are defined in the text describing the figure 3. Also interesting that there is so little moderate. It would be helpful if figure 3 showed 1) all forest, and 2) all non-urban lands (or all lands).
- There is no mention of fire frequency as a metric of value for functional fire in the WUI. It may be that there is too much uncertainty and/or controversy about using or promoting fire in the WUI, but it is a primary disturbance agent for these forests that will occur – planned or unplanned. Using fire in the threat zone would be highly beneficial for these forests, and worth mentioning the value of fire even in the threat zone, particularly given that it is the best defense against future high-intensity fire.

Two points merit additional attention. First, based on Table 7, the total of the defense and threat zones support 56% of all forests in the basin, if the values in the table represent forests. That is a major proportion of the forest that this is prescribing to carry only low flame lengths. It is also curious that the defense zone (usually ¼ mile buffer around built environment) has less area than the threat zone (usually an additional 1 ¼ mile buffer). Does not make sense based on these buffer areas – need to explain the values in the table. Typically, the defense zone has more strict target values for fire safety than the threat zone, both because of proximity and because of ecological impact. The fact that the defense zone occupies such a large proportion of forests in the basin merits some analysis of the impacts this threshold standard in this zone will have on other forest thresholds. On the surface, there would not appear to be a conflict with seral stage, but potentially there could be a conflict with closed canopy targets, particularly for lower elevation forest types where more of the WUI zone exists. I think an assessment of the proportion of each veg type that is in WUI defense and threat would help one evaluate the potential for a conflict. Also, the late seral quality (including but no limited to canopy closure) is also likely to be at odds with 4 ft flame lengths. If so, then it would indicate that high quality and closed late seral conditions are likely to exist only outside of the WUI, and for some vegetation types, it may be that most of the forest outside of the WUI would need to be managed for late seral conditions (given the high percentages of late seral targeted for some types).

The second point focuses on the threat zone. The threat zone represents nearly 25% of all forests and an even greater percentage of lower elevation forest types, I suspect. If nearly 1/3 of all forests are in the defense zone, then the threat zone may be needed to meet other threshold standards. Beyond the potential for conflict among the thresholds, managing > 50% of the forest for low flame lengths will reduce forest heterogeneity and with it the myriad of ecological benefits and services (including biodiversity). Furthermore, the justification for managing the majority of the basin's forests to carry fire only at low intensity is lacking, and alternatively there is ample research to support the value of pyrodiversity in promoting forest health and biodiversity. I suggest that the team rethink fire objectives for the threat zone, and relax the current threshold to incorporate at least low and moderate flame lengths across the majority of the area (a >90% threshold for low and moderate combined might work well). Some moderate severity fire will be important, and will be inevitable as well, so best to embrace it. Also, it will be arguably more compatible with landscape heterogeneity, late seral quality, and overall forest health objectives.

Landscape Fire

A few key points are noted below.

Patch size - Patch size of 40 acres is very small, and the scientific foundation for that value is not well documented in the text. Primary literature should be cited to support this number, but that will be challenging. I believe it reflects an average value based on historical evidence, but the historical data are scant, regionally and temporally specific. Looking forward, I suggest that patch size be based on ecological considerations, namely regeneration and forest connectivity implications. Regeneration is affected, at least in part, by proximity to seed sources (edge effects) and seed dispersal distances could be used to inform patch size thresholds. The shape of the patch has just as much impact – perhaps more – so if the primary concern is about regeneration, then a more ecologically founded measure would be percent (or area) of the forest that is currently at risk of high intensity fire AND exceeds some distance from forests with low risk of high intensity fire. The target of no more than 5% of the forested area at high risk of large patches of high severity fire seems like a good target… probably should state the basis of that target – likely to be, " as low as possible, given that zero is not a realistic option"

High intensity fire - It would be helpful to know the total area/percent of the forest or landscape is estimated to support high flame lengths we have a feeling for the magnitude of the problem. I would think there would also be a threshold for the total amount of high flame length fire, and that it could be informed by the target range of early seral – no more than that range, and that would assume that fire will be the primary source of early seral conditions. Also, what about the spatial distribution of HS fire? There is no mention of that, other than the implicit suggestion that the condition would be distributed equally across all areas.

Fire frequency – Fire frequency is missing, but it is a central feature of fire regimes. HRV is not a great source for setting targets for future fire, but certainly provides relevant context for setting fire frequency objectives. I suggest if a threshold is developed regarding beneficial fire frequencies, that it have broad range of values given that mean fire return intervals (FRI) as stand alone targets are not scientifically defensible.

2. **Are the selected metrics well justified by the supporting rationale?**

<u>Forest Composition</u>

Forest composition metrics that were selected are important and valuable. I suggest that a basin-wide target for each seral stage be established, as well as some measure of old forest quality.

<u>Functional Fire in WUI</u>

Additional rationale and justification is warranted regarding the 90% target for area of forest predicted to carry fire at low flame lengths, given the large proportion (56%) of the forested area in the WUI zones.

<u>Landscape Fire</u>

The patch size and <5% target need justification. Also need to consider patch configuration.

3. **Are there any gaps, limitations, or improvements that should be considered based on data that is readily available today?**

<u>Forest Composition</u>

The two vegetation types that stand out as meriting inclusion in the standards are subalpine conifer and lodgepole pine (together they constitute 15% of the conifer forests in the basin). The document states that there are not plans to manage them, but humans affect every square meter of the basin, whether it is intentional or not, so I suggest being intentional and declarative about all the conifer forest types, if not all the forest types.

It would be helpful to have a map of the CWHR vegetation types included in the document so we could see where these types occur, particularly between low and high elevation (~1700 m) as a basis for their treatment. One option is to include them in one of the three existing groupings. Subalpine conifer is commonly a higher elevation version of sierran mixed conifer, meaning it is Jeffrey pine, red fir, lodgepole pine, maybe some of the higher elevation pines. It could be combined with red fir and some alternative thresholds applied if it is dominated by high elevation pines (e.g. white-bark pine). Lodgepole pine tends to have a bimodal distribution (low and high elevation), so it is not so easily lumped into a group. An alternative to lumping them in or excluding them is to include them as fire-only stand alone types, and at least assign them a fire return interval. You could be conservative and assign them a long FRI, the same FRI as red fir, for example.

The use of CWHR to represent wildlife habitat is broadly supported across the state of California, and it can be used to make inferences about forest conditions as well as habitat suitability across all vertebrates, which is particularly useful for broad-scale, longer term planning. However, we don't have equivalent level of ecological information or understanding across all of the types.

Missing, high-value metrics of forest health that were noted earlier in the review are reiterated here: 1) threshold for amount and distribution of seral stages across the basin; and 2) measures of old forest quality.

Functional Fire in WUI

Fire frequency and the intentional use of fire as a management tool are not mentioned – they would be a valuable addition.

Landscape Fire

Fire frequency is an essential part of fire regimes and their ecological outcomes – needs to be mentioned, if not included in the threshold.

4. **How can the standards be structured to remain adaptable as new or improved data become available?**

All Threshold Topic Areas

I suggest that a brief summary of the limitations of each of the major data sets used as the foundation of the thresholds be included in the update. It will set the stage for two things: 1) recognition and justification of changing to a new, much improved data set, and 2) investment in actively developing better data if/when the opportunity aligns with priorities and funding capacity. It could be in an appendix so it does not detract from the credibility and flow of the document. This information would help identify those data sources that are mostly likely to change in the short term. Vegetation data sources are likely to be the most dynamic and improving rapidly (or so we hope), but there may be others.

I think a commitment to data continuity would be valuable to include and some text devoted to how that is likely to be achieved. Overlapping methods for one or two years is a simple solution to updating data sources over time, with a comparison of methods in the overlap period providing the ability to calibrate values from the two sources so a temporal trend can still be derived. There are other mechanisms as well – I don't think this document needs to commit to one specific approach, just state the commitment and outline one or more approaches that can be used to accomplish a smooth transition from one source to another. It might be best to make a commitment to not transition in the middle of any given 4 or 5-year evaluation period – overlap would occur within an evaluation period (maybe even for the entire evaluation period?), but one method would be used across the entire evaluation period. The overlap would facilitate transitioning to a new source the next evaluation period.

5. **Are the thresholds measurable, feasible to implement, and suitable for long-term monitoring and adaptive management?**

Yes, they are all measurable. The only current threshold that may be challenging to measure meaningfully, based on the premise of patch size having ecologic consequences.

6. **Are the thresholds clearly defined and easily interpretable for managers, policymakers, and the public?**

Suggested added information mentioned above.

7. **Do the targets adequately account for climate change, fire regimes, and other key stressors?**

Change in vegetation type distribution is not specifically accounted for in the description of threshold standard metrics or monitoring. Trees are expected to shift in their distribution in response to climate change, and in the basin that is likely to be expressed by the most significant changes occurring a lower elevations and the drier, east side of the basin.

Hugh Safford Review

Third-Party Review of the Tahoe Regional Planning Agency Forest Health Thresholds

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October 30, 2025

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I conducted a draft review of the threshold values for TRPA in July 2025, and this report is based partly on the foundations of that work. I began my July review by considering the desired conditions we built for the Lake Tahoe Basin Management Unit (LTBMU) management plan back in 2008-2010 (I worked for the US Forest Service at that time, and was assigned to the planning team by the Regional Office). I also consulted germane literature that has been published since 2010 in order to consider whether newer information justified changes in those desired conditions. Importantly, there has been an explosion of fire and forest science in the Sierra Nevada since the early 2000s, and most of the references that I consider today to be fundamental to these questions were published after 2010, i.e. after the completion of our work with the LTBMU plan. See Appendix I for the text of my original review of the thresholds.

As part of my review, I also read through the Forest Health Threshold draft document as provided to me. I have made comments and suggested edits directly into that document, which is attached to my submission.

Review Questions

1. **Scientific Foundation of Desired Condition Targets**
   A. Are the proposed thresholds consistent with current science and best practices in forest ecology and management?

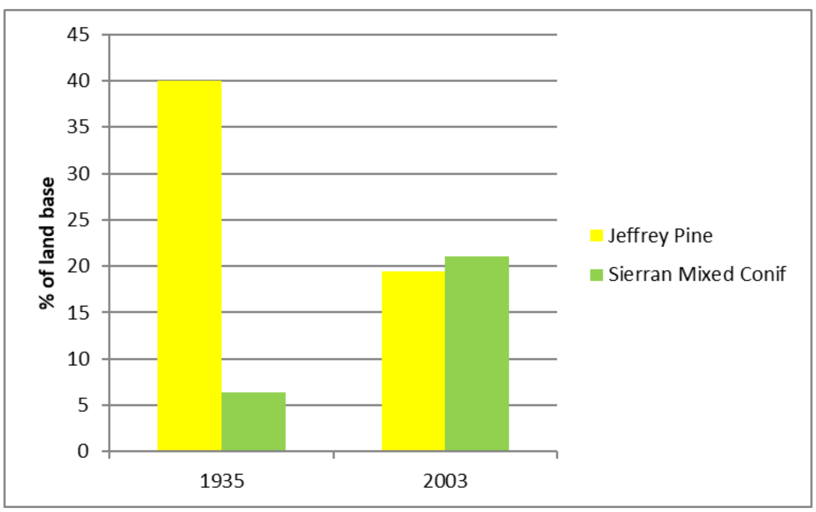
      In my opinion, the proposed thresholds are generally consistent with current science/best practices in forest ecology and management. I reviewed the threshold values in July of this year, and made several suggestions which have already been applied. I've included my original comments on the thresholds below, in Appendix I. In addition, below I suggest that relative Stand Density Index might be a useful addition to the thresholds.

   B. Are the selected metrics (e.g., basal area, trees per acre, seral stage, canopy cover) well justified by the supporting rationale?

These metrics are appropriate because they are standard metrics that are used by managers to describe, understand, and manage forest habitats. These metrics are widely used, and they are a common language among foresters worldwide. These metrics are easily measured and described, forest treatment prescriptions are based on these metrics, and science has shown that they are important drivers of ecological composition, structure, and function.

C. Are there any gaps, limitations, or improvements that should be considered based on data that is readily available today?

A. The spatial footprints of the vegetation types that TRPA assesses are fixed in place by the process. However, large areas of forest that used to be dominated by Jeffrey pine have moved to White fire-dominated stands as a result of logging of the pines and fire suppression. See the following graphic, which compares the % of LTB landscape mapped as Jeffrey pine and mixed conifer by the 1930's USFS VTM mapping project versus the 2003 USFS EVEG map. Certainly classification differences have a little bit to do with this, but the difference is nonetheless stark (and it much more stark if you use the forest type areas in Table 1 in the Forest Health thresholds doc!). I think there should also be incentive to return drier parts of the modern white-fir landscape to pine domination, if/when/where possible. This is not currently captured in any of the thresholds



B. In my comments in the marked up Thresholds doc, I note that adding a threshold based on Relative Stand Density Index (RSDI) might be a useful addition. It would take a little effort to think this through completely, but the framework could provide stand- and landscape-level targets that could be modulated based on landscape physiography (e.g., dry vs moist slopes, ridgetops, canyon bottoms, riparian, etc.). At the moment the TRPA guidelines use maximum densities of stems by seral stage, which are based primarily on empirical measurements made in modern reference stands, historical data, or on modeling based on growth rates and historical fire regimes (LANDFIRE 2020). The guidelines are therefore based on a match-the-photo-of-historical-conditions methodology, which is pretty standard for western US restoration. RSDI would be a more mechanistic guideline, based on actual within stand relationships between density and biomass that drive tree growth, competition, and mortality, and would be a useful addition to the current framework I think.

RSDI is used in forestry most often to manage timber stands to maximize stand growth for production, but as North et al. (2022) note, it can also be used to maximize individual tree growth/vigor by creating a low competition environment which minimizes density-driven stress and mortality. SDI is a measure of the number of 10” dbh trees (25 cm) in a unit area that would be equivalent to the actual combination of biomass (volume) and density in the stand in question (see Long 1985; Long and Shaw 2005, 2012). RSDI is easily calculated in the Forest Vegetation Simulator and other similar software or in a spreadsheet.

RSDI can be applied at the landscape scale to evaluate variability in local growth conditions and whether such variability is aligned with resource availability and potential stresses (drought, beetles, etc.). North et al. (2022) applied RSDI to historical mixed-conifer forest data from USFS inventories on the Sierra and Sequoia National Forests. They found that mean RSDI values in the historical data (before logging and fire suppression) averaged 23–28% of maximum SDI, which means the stands were experiencing very little inter-tree competition (see below), but the interquartile ranges were 14–36%, which could be used as a measure of variability across wet/high productivity and dry/low productivity sites.

According to Long and Shaw (2005 and 2012), 0-24% of the maximum SDI represents the zone of “open growth” or competition-free growth, which is where tree size is maximized; 25-24% represents the onset of competition; 35-59% is “full site occupancy”, which is where stand volume is maximized; and ≥60% is the zone of “imminent mortality”, where water and resource competition are severe and density-dependent mortality factors become major issues. North et al. (2022) provide a maximum SDI for “xeric-mixed conifer” (this would apply to the widespread Jeffrey pine-white fir forest in the LTB) of 450. Therefore, in stands where the management objective is to maximize the size of trees in open canopied configurations, RSDI should be <113 (25% of 450). Using the North et al. (2022) variability from above, a range of 15-35% in RSDI could be included, with higher RSDI in moister/higher productivity sites, and lower RSDI in drier/lower productivity sites. In places where the management desired conditions include higher densities and more closed canopies, RSDI values between 25% and 59% could be targeted. The 60% value (imminent mortality) could be an upper threshold for all stands where limiting density-dependent mortality is desired.

Using data from North et al. (2022), and Long and Shaw (2005, 2012), here is a table with approximate max SDI values for the vegetation types covered in the thresholds:

Forest type	Max SDI (metric; 25-cm trees ha^{-1})*	Max SDI (Imperial; 10-in trees ac^{-1})	RSDI: 25%/35%/60% for Imperial measures
Jeffrey pine	902	365	91/128/219
Dry mixed conifer	1112	450	113/158/270
Moist mixed conifer	1359	550	138/193/330
Red fir	1662	670	168/235/402

*25 centimeters = 10 inches

D. How can the standards be structured to remain adaptable as new or improved data become available?

Obviously periodic review is of fundamental importance.

A major issue when one is trying to use spatial data for long-term monitoring: the data resolution continually gets better and the desire is always to upgrade. This makes it impossible to string together many years of spatial monitoring, since the older data are always of lower resolution. I recommend that TRPA commit to monitoring that can be done for the long-term, which means (1) committing to on the ground techniques whenever possible, and (2) ensuring that when new spatial data come online, there is a way to generalize the newer data appropriately to permit comparison to older baseline and trend data.

As an aside: how is it that the LTB doesn't have a funded monitoring program for vegetation and fire/fuel conditions? It would be easy to design and implement

2. Applicability and Interpretability

A. Are the thresholds measurable, feasible to implement, and suitable for long-term monitoring and adaptive management?

The thresholds as currently defined, including the new ones, are relatively easy to measure, and the they are based on standard measures of forest and fire conditions, which are easy to implement and can theoretically be followed over time. As I noted above, the challenge to using remote sensing-based products or fire modeling is that the data and models improve over time, therefore it is necessary to design a process where valid comparisons can be made between older data and newer data. This is not a trivial problem. This also underlines the value of having standardized on-the-ground measurements and inventory/monitoring processes in place.

B. Are the thresholds clearly defined and easily interpretable for managers, policymakers, and the public?

Yes, I think they are. The seral stages as defined are relatively easy to ID on the ground, and also through typical forest inventory and mapping. And the modeled flame length is a very common way of gauging fire intensity/hazard. I like the addition of the modeled high severity patch size.

One complication is that yellow pine and mixed conifer forests, especially the drier ones, did not historically burn in stand-replacing fires that left obvious seral stages across the landscape. Burning was mostly understory with only patchy overstory mortality. Stands were multi-aged as a result, and it would have been difficult to actually see different patches on the landscape (with some obvious exceptions being where topography was a major driver of different disturbance intensities and frequencies). The lower elevation forest today is probably much more characterized by visible seral stages than it was before the Comstock logging. This is all to say that basing management on seral stages for these forest types is a little challenging. See my comments about adding SDI-based thresholds possibly.

C. Do the targets adequately account for climate change, fire regimes, and other key stressors?

In my recommended revisions to the density and basal area thresholds, I generally took the lower end of the variability ranges from the models and empirical data, in order to account for the pronounced drying and warming that is happening. I also hewed more closely to the reference data from northern Mexico, which are from a slightly more arid system (but have the same tree species). This is reflected in the information in Safford and Stevens (2017).

Using SDI as another type of threshold/guideline would be a good way to incorporate stand-density-driven issues tied to drought, fire, insects, and other mortality agents, and it would also be an efficient way to build stand conditions that were more likely to promote big trees and low densities, which are much more resistant to fire, drought, and bugs.

Literature cited in main body and appendix

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- Taylor, A.H., R.S. Maxwell, C. Skinner, and H.D. Safford. 2012. Identifying spatially explicit reference conditions for forest landscapes in the LTB, USA. Report to the Lake Tahoe Basin Management Unit and the US Bureau of Land Management. 41 pp.
- Taylor, A. H., A. M. Vandervlugt, R. S. Maxwell, R. M. Beaty, C. Airey, and C. N. Skinner. 2013. Changes in forest structure, fuels and potential fire behaviour since 1873 in the Lake Tahoe Basin, USA. *Applied Vegetation Science* 17:17–31.
- Young, D., M.D. Meyer, B.E. Estes, S.E. Gross, A. Wuenschel, C.M. Restaino, and H.D. Safford. 2020. Forest recovery following extreme drought in California, USA: natural patterns and effects of pre-drought management. *Ecological Applications* 30(1): e02002. (the important info in this

case is the NRV tables included in the supplementary material; the info mostly comes from the Safford and Stevens citation above)

Annotated review comments sent to TRPA on July 6, 2025

From: Hugh D Safford <hdsafford@ucdavis.edu>
Sent: Sunday, July 6, 2025 1:19 PM
To: Mason Bindl <mbindl@trpa.gov>; hugh@vibrantplanet.net <hugh@vibrantplanet.net>
Cc: Dan Segan <dsegan@trpa.gov>; Kat McIntyre <KMcIntyre@trpa.gov>; Andrew McClary <AMcClary@trpa.gov>
Subject: Reply: Updated Forest Health Threshold Targets for the Tahoe Basin

Hi y'all,

Yesterday and this morning I looked over the desired conditions we built for the LTBMU plan back in 2008-2010. I also consulted germane literature that has been published since 2010 in order to consider whether newer information would convince me to recommend changes in those DCs.

There has been a veritable explosion of fire and forest science in the Sierra Nevada since the early 2000s, and almost all of the references that are fundamental to these questions were published after 2010. Obviously we didn't have access to any post-2010 info when we built the DCs. Here is a list of the papers, books, and government publications that I consulted in my review (alphabetical order):

- LANDFIRE. 2020. Biophysical Settings descriptions, August 2020 revised models. https://landfire.gov/vegetation/bps-models
- Maxwell, R.S., A.H. Taylor, C. Skinner, H.D. Safford, R. Isaacs, C. Airey, and A. Young. 2014. Landscape scale modeling of reference period forest conditions and fire behavior on heavily-logged lands. *Ecosphere* 5(3): Article 32
- Meyer, M. and North, M. 2019. *Natural range of variation of red fir and subalpine forests in the Sierra Nevada bioregion*. Gen Tech. Rep. PSW-GTR-263. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station.
- Safford, H.D, and J.T. Stevens. 2017. *Natural range of variation for yellow pine and mixed conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA.* General Technical Report PSW-GTR-256, USDA Forest Service, Pacific Southwest Research Station, Albany, CA. 229 p.
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- Taylor, A. H., A. M. Vandervlugt, R. S. Maxwell, R. M. Beaty, C. Airey, and C. N. Skinner. 2013. Changes in forest structure, fuels and potential fire behaviour since 1873 in the Lake Tahoe Basin, USA. *Applied Vegetation Science* 17:17–31.
- Young, D., M.D. Meyer, B.E. Estes, S.E. Gross, A. Wuenschel, C.M. Restaino, and H.D. Safford. 2020. Forest recovery following extreme drought in California, USA: natural patterns and effects of pre-drought management. *Ecological Applications* 30(1): e02002. (the important info in this case is the NRV tables included in the supplementary material; the info mostly comes from the Safford and Stevens citation above)

Based on my review, here are the changes I would recommend in your forest threshold indicators:

Jeffrey pine (aka yellow pine and dry mixed conifer):

1. Change the late seral target density to 55 trees per acre. Reasoning: Although the Young et al. tables give a 60.7 mean for the sites in their Table S2 that are from the eastern Sierra Nevada or northern Mexico, the Maxwell et al. (2014) summary gives 45.6 and the LTB-specific Taylor (2012/2013) summary gives 27(!). Note: the Taylor paper is a plot reconstruction, has limited geographic coverage, and will miss trees that have completely decayed
2. Change the late open canopy seral stage target % range to 40-50 (from the current 45-50). From Safford and Stevens 2017 and LANDFIRE 2020 models

2. White fir/Sierra Mixed Conifer (aka moist mixed conifer)

   1. Change late seral basal area to 180 sq ft/ac (from 200 currently). The Young et al. Table S1 gives a mean of 194 for their west-side and moister sites, but the Maxwell et al. mean is 180 and Taylor et al. 2012/2013 mean for the LTB is 130.
   2. Change mid seral basal area to 130 (from 150 currently). This is based on the above change (same % change).
   3. Change late seral density to 75 (from 80 currently). The mean from the Young et al. Table S2 for their west-side/moister sites is 75, Maxwell mean is 80, and Taylor mean (LTB) is 53.
   4. Change mid seral density to 90 (from 100 currently). This follows from the above change (same % change), and also on the desire to reduce density-dependent morality in mid-seral stands.
   5. Change the mid-open canopy seral stage % range to 15-20 (from 10-15 currently). From Safford and Stevens 2017 and LANDFIRE 2020 models
   6. Change the late open seral stage % range to 25-35 (from 30-40 currently). From Safford and Stevens 2017 and LANDFIRE 2020 models

    7. Change the late closed seral stage % range to 15-25 (from 20-30 currently). From Safford and Stevens 2017 and LANDFIRE 2020 models

3. Red fir

    1. Change late basal area to 250 sq ft/ac (from 350 currently). Reasoning: Meyer and North (2019) give 253, Maxwell gives 240, and Taylor et al. give 243.

    2. Change mid seral basal area to 175 (from 250 currently). Based on above change, reduction made by same %.

    3. Change mid closed canopy seral stage % range to 15-25 (from 20-30 currently). From Meyer and North 2019 and LANDFIRE 2020 models

    4. Change mid open seral stage % range to 15-25 (from 5-15 currently). From Meyer and North 2019 and LANDFIRE 2020 models

    5. Change late open seral stage % range to 30-40 (from 15-25 currently). From Meyer and North 2019 and LANDFIRE 2020 models

    6. Change late closed seral stage % range to 20-30 (from 25-35 currently). From Meyer and North 2019 and LANDFIRE 2020 models

Overall notes:

1. I have tended to recommend values that are a little below the reference means, as the climate is currently moving in a direction that will support fewer live trees than the historical reference conditions, which were coincident with the Little Ice Age

2. We remodeled the state and transition models for the BpS component of LANDFIRE in 2019 and 2020 and the new results are included in the August 2020 release (see first entry in the bibliography above). New information and data were included, and we trust these models more than the models that were consulted by the LTBMU plan revision team.

3. If you would like I can build a formal report around these suggestions, but we'd need a contract to do that. The work wouldn't be substantial, but I am swamped this summer.