Comments on the Historic Range of Variability in Chaparral, Aspen, and Conifer Forests in the Sierra Nevada and South Cascades

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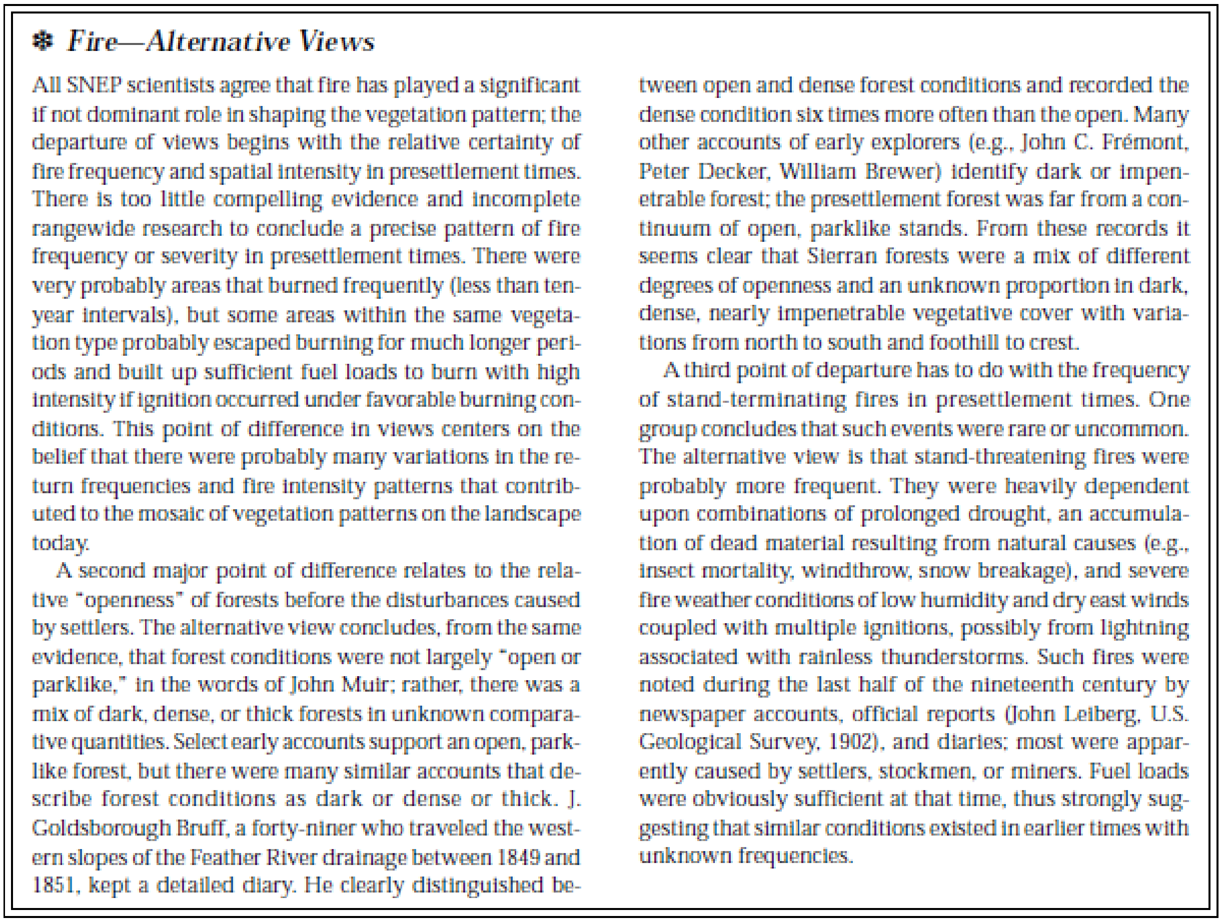
Introduction

I appreciate the opportunity to comment on the draft descriptions of the natural range of variability (NRV) in chaparral, aspen, and yellow pine and mixed conifer forests in the Sierra Nevada prepared by the US Forest Service. These are lengthy and important documents with significant implications for understanding the ecology of these vegetation types and their potential restoration and management needs. I wish there had been more time to allow more careful review of these reports and to prepare my comments.

To help ensure that these reports may qualify as systematic evidence reviews that fully capture the existing science and incorporate broader perspectives, the reports should be peer-reviewed by independent experts who are not affiliated with the Forest Service, nor funded or chosen by the Forest Service. In addition, there is a need in a systematic evidence review to explain explicitly the criteria for screening and addressing existing literature. Guidelines for preparing a systematic evidence review are at the following site: http://www.prisma-statement.org/statement.htm.

A peer-review is particularly needed because there have been widely varying views about historic fire regimes in the Sierra Nevada as a result of different perspectives. This was exemplified in the Sierra Nevada Ecosystem Project, in which Box 1was presented in Chapter 4 (page 86) of the SNEP report (SNEP 1996).

Box 1. A summary of the alternative views of a subset of scientists participating in the analysis of the past and present role of fire in the Sierra Nevada Ecosystem Project (SNEP 1996). From Chapter 4, page 86, of the SNEP report:



Fire—Alternative Views

All SNEP scientists agree that fire has played a significant if not dominant role in shaping the vegetation pattern; the departure of views begins with the relative certainty of fire frequency and spatial intensity in presettlement times. There is too little compelling evidence and incomplete rangewide research to conclude a precise pattern of fire frequency or severity in presettlement times. There were very probably areas that burned frequently (less than ten-year intervals), but some areas within the same vegetation type probably escaped burning for much longer periods and built up sufficient fuel loads to burn with high intensity if ignition occurred under favorable burning conditions. This point of difference in views centers on the belief that there were probably many variations in the return frequencies and fire intensity patterns that contributed to the mosaic of vegetation patterns on the landscape today.

A second major point of difference relates to the relative "openness" of forests before the disturbances caused by settlers. The alternative view concludes, from the same evidence, that forest conditions were not largely "open or parklike," in the words of John Muir; rather, there was a mix of dark, dense, or thick forests in unknown comparative quantities. Select early accounts support an open, parklike forest, but there were many similar accounts that describe forest conditions as dark or dense or thick. J. Goldsborough Bruff, a forty-niner who traveled the western slopes of the Feather River drainage between 1849 and 1851, kept a detailed diary. He clearly distinguished between open and dense forest conditions and recorded the dense condition six times more often than the open. Many other accounts of early explorers (e.g., John C. Frémont, Peter Decker, William Brewer) identify dark or impenetrable forest; the presettlement forest was far from a continuum of open, parklike stands. From these records it seems clear that Sierran forests were a mix of different degrees of openness and an unknown proportion in dark, dense, nearly impenetrable vegetative cover with variations from north to south and foothill to crest.

A third point of departure has to do with the frequency of stand-terminating fires in presettlement times. One group concludes that such events were rare or uncommon. The alternative view is that stand-threatening fires were probably more frequent. They were heavily dependent upon combinations of prolonged drought, an accumulation of dead material resulting from natural causes (e.g., insect mortality, windthrow, snow breakage), and severe fire weather conditions of low humidity and dry east winds coupled with multiple ignitions, possibly from lightning associated with rainless thunderstorms. Such fires were noted during the last half of the nineteenth century by newspaper accounts, official reports (John Leiberg, U.S. Geological Survey, 1902), and diaries; most were apparently caused by settlers, stockmen, or miners. Fuel loads were obviously sufficient at that time, thus strongly suggesting that similar conditions existed in earlier times with unknown frequencies.

Although there have been a number of studies published since the SNEP report, the issues raised in Box 1 remain just as valid today. The alternative view presented in Box 1 raises key issues that need to be addressed. In particular, the interpretation of Leiberg (1902) requires careful attention. It remains the only study that has documented historical patterns of fire severity over a large area. A large area is needed to capture the range of spatial variation in heterogeneous landscapes. The legend of the Leiberg (1902) map is quite clear about the severity categories mapped, and the field crews spent several years surveying every section of the large study area, adding to the value of the map. It has been assumed by many on the SNEP team that the areas Leiberg mapped as severely burned had been chaparral instead of forest (McKelvey 1996). But, as demonstrated in Box 1, there was no consensus about interpreting historical data. No evidence has been presented that suggests that Leiberg mistook areas that burned as chaparral with areas that burned as forest. Since Leiberg was relying on dead trees to identify burned forest, it seems unlikely that he or his crew would have mapped areas with no dead trees as burned forest. In addition, his maps specifically distinguished chaparral from forests. Further still, the 31 FIA plots within the areas mapped as burned forest by Leiberg and his co-workers all support forest vegetation today, not chaparral.

Lastly, Leiberg states that "a large proportion" of the 75-100% burned timber that he mapped dated back to "the early part" of the 19th century, prior to settlement (Leiberg 1902 [page 41]). Thus, most of the fires he mapped were not set by settlers. Accordingly, the Leiberg mapping of

>75% mortality by timber volume (specifically the map itself showing the locations and extent of this mortality) needs to be explained. It is also important to point out that there are no landscape scale data that refute the findings of Leiberg (1902).

Chaparral NRV

Chaparral is an often unappreciated vegetation type, particularly in landscapes where forests occur along with chaparral. But there is increasing recognition of the value of chaparral to biodiversity, as evidenced by this review, and several of the sources cited (e.g., Nagel and Taylor 2005). The review does a nice job of synthesizing a lot of information about chaparral and what is known about its historical condition.

As discussed in the draft Chaparral NRV document, it is difficult to reconstruct historical conditions for chaparral. The vegetation commonly burns by crown fire. Although these fires usually leave shrub skeletons, they do not leave evidence that allows precise reconstruction of historical fire regimes. What's more, fire has changed throughout the Holocene. The review explains these issues.

The review does not make a distinction between chaparral created by fire vs. logging. The review would be improved by clearly making this distinction. Where fire creates complex early successional vegetation dominated by chaparral, there are abundant legacies of the pre-disturbance community, such as snags, rhizomes, seed banks etc., which are linked to high post-fire biodiversity (reviewed by Odion and Sarr 2007, DellaSalla et al. 2013). Chaparral or other early successional vegetation that follows clear cutting or group selection lacks many of these legacies and may not support characteristic diversity found in complex early successional vegetation (Swanson et al. 2010). Here, I focus on naturally created chaparral and assume that chaparral created by logging, including group selection, does not accomplish the goals of restoring characteristic, complex early successional conditions.

There are several management activities impacting chaparral that need to be explained in a revision of the NRV document for it to be a systematic assessment of chaparral loss.

1. **Type conversion to exotic grasslands or other exotic vegetation**. This may occur when grasses, particularly cheatgrass (*Bromus tectorum*), invade after disturbances. This was documented by McGinnis et al. (2010) in the American River Drainage. The invaded areas have reburned on short rotation, completing the type conversion to cheatgrass. The odds of reburning are greatly facilitated by cheatgrass, particularly where there are sources of human ignition. This type conversion is a relatively recent phenomenon, and it has likely not yet caused much loss of complex early successional habitat in the Sierra Nevada. Nonetheless, the creation of a grass fire cycle is an important phenomenon in southern California and in all the Mediterranean regions of the world, as well as the Great Basin of North America. The common denominators are annual grasses and human ignitions. While the review mentions that type conversion to grasslands is too frequent in southern California, it does not mention the potential for this in the Sierra Nevada. The problem should be described and the locations of type conversion documented as best as possible. This would be helpful to management aimed at controlling invasive grasses because cheatgrass invasions can be minimized by avoiding activities that spread the grass into burned

areas, and by reducing disturbances known to promote cheatgrass (e.g., logging after fire (McGinnis et al. 2009)). In addition, the potential for other grasses to invade and promote a grass fire cycle should be considered.

There are other invasive species threats to Sierran chaparral. Scotch broom is well-established in the lower montane zones around the latitude of Lake Tahoe (not in the Lake Basin though). Scotch broom responds well from seed following fire, but also has readily germinable seed that can respond to any disturbance (Odion and Haubensak 2003). The seeds are produced in great abundance and there may be thousands of them in every square meter of soil around a scotch broom plant. The seeds are dispersed well along roads and trails and downslope via runoff (Swezy and Odion 1997). Scotch broom is little browsed by wildlife and consequently may have an advantage over native shrubs like *Ceanothus* spp. after fire. Thus, fire or removal of woody vegetation could lead to type conversion to scotch broom in and around areas where it is currently established, even where it occurs in low densities. This invasive species problem creates a situation where a beneficial disturbance, fire, may no longer be beneficial. Unfortunately, this is a very difficult management problem. The best case scenario may be preventing the spread of scotch broom by limiting activities that disperse its seed to new areas. Forest thinning is one activity that has the potential to spread scotch broom. It may disperse the seed and, by opening the forest canopy, provide prime conditions for the growth of scotch broom, a light-demanding species. Thinning has been found to cause invasives to establish (Stephens et al. 2012), which could undermine prevention efforts. A fire in an area where even small numbers of broom have established could lead to partial or complete type conversion.

2. Post-fire logging and associated activities. Areas that have been logged after fires that have not type converted to cheatgrass have been converted to plantations. It would be helpful for the NRV document to estimate the amount of chaparral that has been lost this way. In addition, it would be helpful to assess how much may be lost in the future based on likely active management scenarios. It should be possible to quantify the loss in recent decades on public lands by querying USFS databases of management activities.

3. Mastication. As with post-fire logging, loss of chaparral has occurred due to mastication. The locations where the loss of chaparral has occurred due to mastication needs to be described and quantified. Once again, it should be possible to quantify the loss (past and ongoing) caused by mastication by querying USFS records of management activities. In addition, there could be some assessment of future losses based on projected future amounts of chaparral mastication.

4. Fire suppression (suppression of either the occurrence of fire or suppression of fire behavior). As discussed in the NRV review, montane chaparral relies on partial or complete stand-replacing fire for its maintenance. In the absence of stand-replacing fire in much of the chaparral in the Sierra Nevada, succession to forest occurs. In the past, succession to forest could be offset by the creation of new chaparral habitat by stand-replacement fire in forests (Leiberg 1902, Show and Kotok 1928, reviewed in Odion and Hanson 2006, 2008). With fire suppression, the processes of chaparral maintenance and creation by fire is reduced (Hanson and Odion 2013). This is discussed in the NRV chaparral review. However, I found this discussion to be largely in conflict with conclusions of the NRV review on yellow pine and mixed conifer forests, which

asserts that forests have become more, not less, susceptible to stand-replacing fire (which would mean that chaparral is increasing). Obviously, the two documents need to be consistent.
The NRV chaparral review does conclude that “large, severe fires are increasing the extent of some chaparral dominance.” However, this is ambiguous. It does not mean that chaparral dominance is increased over its historical amount, nor that chaparral is not being reduced by fire suppression, as suggested in the yellow pine/mixed conifer NRV document.

An analysis of the past vs. present rotation of stand-replacing fire in conifer forests of the Sierra Nevada is presented below in the section on the yellow pine/mixed conifer NRV. The analysis concludes that fire that generates chaparral and other complex early successional vegetation currently occurs much less often compared to historically in the mid-montane zone. In addition, no trend in the annual amount of this fire was found.

Minor comments on chaparral

- I think the author did not realize that red fir in Leiberg (1902) applies to *Psuedotsuga menziesii* (Douglas-fir), and not *Abies magnifica*.
- Work by Tom Parker and his students has established a role for manzanita in the facilitation of conifer regeneration. This is mediated by mycorhizzal fungi.
- Nitrogen-fixation by Ceanothus, and increases in soil nutrients via fine root turnover of *Ceanothus* and *Arctostaphylos,* may play an important role in long-term site productivity (see publications of Matt Busse and colleagues, e.g., Busse et al. (1996)).
- Chaparral has exceptional value in stabilizing slopes and reducing sedimentation in watersheds managed for water production (see studies from San Dimas experimental forest). While this chaparral value is greater in southern California than the Sierra Nevada, it is worth mentioning (along with the previous 2 items) in the interest of improving public appreciation for chaparral vegetation.
- *Purshia tridentata* and *Ambrosia dumosa* are not chaparral plants.

Indicators of chaparral condition

The best indicators of chaparral condition may be the extent of the vegetation, particularly in situations where it is successional to forest vegetation, and the rotation of fire that generates and maintains chaparral. The trend in the extent of chaparral, and thus chaparral condition, is a decrease, or continued movement away from the historical condition. This is because forests are replacing chaparral due to longer fire rotations under fire suppression. If fire increases due to climate change, this trend may end. However, fire would have to increase substantially to return to past levels, and there is no ongoing trend of high-severity fire (Hanson and Odion 2013).

Aspen NRV

The draft Aspen NRV document concludes that aspen is within its historic range of variation. Here, I review information from an analysis of aspen at Lassen National Park that indicates that aspen has declined dramatically there. I review this information here because it was not available to the authors of the Aspen NRV. The information is presented in a draft Condition Assessment Report prepared for the National Park Service (Adamus et al., in revision).

To evaluate how major vegetation types may be shifting in abundance during the last 75 years due to successional processes at Lassen, Adamus et al. (in revision) performed a quantitative change detection study, comparing a historic (circa 1930s) vegetation map to a modern one. The historical (1930s) VTM maps are considered very accurate due to the extensive field work done to support them. The current map was done to the standards of the National Park Service Vegetation Mapping Program, and therefore is likely to be very accurate (> 80%) as well. The same methods for determining changes from the 1930s to the present time used as in Thorne et al. (2008) were used. This publication is familiar to the authors of the NRVs as it is cited in the NRV reports as an important source of estimates of changes in abundance of different vegetation.

Based on the analysis, the 95 ha historical extent of aspen in the 1930s has been almost completely replaced by conifer forests, primarily lodgepole pine, red fir, and white fir (Adamus et al. in revision). There was particularly significant aspen loss in the Warner Valley in the Park's southeast corner. Outside the Park (not included in the 95 ha lost within the park) there was a much greater loss in the Warner Valley. Much of this valley used to have a large, continuous corridor of aspen. It is now almost completely replaced by white fir forests.

The Aspen NRV document provides a nice review of aspen ecology. However, I make some additional observations here that may be important to consider. As the NRV points out, aspen is well-recognized as an early successional and historically fire-dependent species in coniferous forest landscapes of the Sierra Nevada and southern Cascades (Pierce and Taylor 2011). However, aspen may create an environment that facilitates conifer growth. For example, growth rates of conifers have been found to be faster in aspen stands than pure conifer stands (Peterson and Squiers 1995a-b). Once overtopped, the shade intolerant aspens release resources to conifers. Aspen do not maintain dormant seed banks and often reproduce by sprouting from roots. Thus, resiliency to long fire-free periods depends on the lifespan of root systems, as well as the availability of seed to disperse from surrounding areas. Reproduction from seed has been found to be common after high severity fire, even where no aspens were nearby (Romme 2005). Establishment of aspen from seed is highest in the most severely burned areas. Greater fire severity not only promotes aspen seedling establishment, but helps prevent conifers from surviving in the stand to compete with the young aspens. At Yellowstone, the conifers killed by fire were a key to survival of young aspens because downed branches and logs from these trees helped inhibit ungulate browsing (Ripple and Larson 2001, Turner et al. 2004). The ecology of aspen makes fire the best tool for restoring stands because mechanical removal of conifers could reduce the flammability of the stand, favoring conifers in the long run, and because removing the conifers will preclude their post-fire role in protecting young Aspen growth from ungulate grazing. Treatments that reduce fire severity will also reduce opportunities for aspen to regenerate from seed (Romme et al. 2005). These aspects of aspen ecology may be helpful for considering how to restore aspen to its NRV.

Indicators of aspen condition

An indicator of aspen condition may be the extent of the vegetation, particularly in situations where it is successional to forest vegetation, as well as the rotation of high severity fire favoring aspen. The trend in aspen cover appears to be a decrease, or continued movement away from the historical condition. I suspect that the current amount of aspen may be outside the NRV, at least in the southern Cascades and northern Sierra Nevada. This is because conifer forests are replacing aspen due to longer fire rotations under fire suppression. If fire increases due to climate change, this trend may end. However, fire would have to increase substantially to return aspen to past levels, and there is no ongoing trend of high-severity fire (Hanson and Odion 2013). Aspen is best restored by wildfires because it is adapted to stand-replacing fire, which is largely infeasible in prescribed fires. Thus, the importance of monitoring the rotation of high-severity fire as an indicator of aspen condition.

Yellow Pine and Mixed Conifer Forest NRV

This review also does a nice job of pulling together a large amount of information. In fact, it is considerably more detailed than the chaparral and aspen reviews. Nonetheless, there is key information that is not included that is needed to make this NRV a systematic evidence review. In particular, as discussed in the introduction to these comments, the Leiberg (1902) fire severity map and its implications are not explained (there is only mention of some text on forest where "total destruction by fire" occurred). The Leiberg map represents the only spatially explicit rendering of high severity fire over a large landscape. There are also problems in the yellow pine/mixed conifer NRV with the interpretations of some studies. I focus on these issues and provide comments on specific sections.

Drought (beginning on line 594)

This section only discusses the potential for increased drought stress with climate change. Although temperatures are increasing, increasing atmospheric $C0_2$ helps mitigate this because of the effect that higher $C0_2$ availability has in increasing a plant's water use efficiency (stomata need not be opened as much for C02 uptake, meaning that water loss due to transpiration is lower). This increased water use efficiency is the explanation that has been used to explain why growth rates of trees in drier western coniferous forests have increased in recent decades (Soulé and Knapp 2006, 2011) and why water limited forests in other parts of the world have increased growth rates (Huang et al. 2008). Forests in general in the Pacific Northwest, particularly in upper montane zones, have been found to have increased growth rates in recent decades (Latta et al. 2009), despite warming temperatures. It would make the NRV assessment more informative to include this topic and the potential implications on vegetation and fire.

Background: Fire Regime (starting on line 717)

The description of the historical fire regime as low-moderate implies that no high-severity fire of any significance naturally occurred. This conflicts with substantial evidence within this same NRV document and with evidence presented in the NRV document on chaparral (see Figure 3 of Chaparral NRV, also, amounts of historic high-severity fire are discussed below). Low and moderate severity fire were historically more common than high-severity fire in yellow pine and mixed conifer forests, but high-severity fire has a disproportionate impact that is much more substantial on a per acre basis. It leaves a far longer lasting imprint on landscape pattern and successional diversity, and therefore is of particular interest (hence the focus of this NRV on high-severity fire). The description of the fire regime as low to moderate in severity is like a description of the seismic regime along the San Andreas fault as low to moderate in magnitude. Even though most of the seismic events are low to moderate in magnitude, a description of only these events would be misleading and fail to convey critical information for understanding the regime. Since the fire regime does have high severity fire at rates causing significant effects on vegetation, mixed with low- and moderate severity fire, it seems much less ambiguous to call it a mixed-severity regime. The term mixed-severity implies that some high-severity fire is mixed with generally greater amounts of low- and moderate-severity fire, so it fits much better than low-moderate as a descriptor of the historic fire regime.

Fire Frequency (beginning on line 806)

Composite fire return intervals only tell us how often a fire occurred somewhere within an area of interest (reviewed by Baker 2009). They do not tell us how much area burned in fires, and hence the actual fire frequency in the area. In addition, because fire scar studies do not include every location in the area of interest in a probabilistic sampling scheme, the area of inference is limited and, strictly speaking, unknown and unknowable (Johnson and Gutsell 1994). Fire scars may also selectively record more older fires that occurred when recorder trees were smaller (i.e., large trees may be less prone to recording fires). Due to the ambiguity of composite fire scars, the fire rotation as a descriptor is strongly preferred over the composite fire interval, and fire researchers increasingly avoid the use of the composite fire interval (e.g., Romme et al. 2009). An explanation of the methodological limitations of the composite fire interval approach should be added to the description of composite fire intervals in the yellow pine/mixed conifer NRV. These limitations are described in considerable literature (e.g., Johnson and Gutsell 1994, Minnich et al. 2000, Baker and Ehle 2001, Baker 2009). In addition, the importance of using the fire rotation instead of composite fire interval needs to be stressed.

Fire Severity (starting on line 890)

Low severity fire may be defined as 0-25% or 30% mortality, but this does not mean that it averages 12-15% mortality as speculated in the NRV. Based on Figure 4 of Miller et al. (2009), disproportionately more area that burns with 0-25% mortality burns with 0-5% mortality.

The kind of mortality discussed is not specified. Mortality also needs to be assessed specifically in terms of basal area mortality, not canopy mortality. Ninety-five percent canopy mortality may mean zero basal area mortality for some species (i.e., 100 percent survival and no population turnover, so low-severity) and high mortality for other species, so it is quite ambiguous to use canopy mortality. In contrast, high-severity fire may more conventionally and clearly be defined as 75-80% basal area mortality (Agee 1993). What would be the proportions of high-severity fire in contemporary fire regimes if high-severity fire was defined as 75-80% basal area mortality? This needs to be presented.

The yellow pine/mixed conifer NRV presents evidence that proportions of high-severity fire are greater in contemporary vs. historic fire regimes. However, this does not necessarily indicate that it is because of an increase in high-severity fire. The effect could occur due to a decrease in low-severity fire caused directly by current fire suppression efforts. A reduction in low-severity fire would be expected since fire suppression is more effective in suppressing low vs. high severity fire. Fires that would have historically burned for a long period of time under mild conditions (until fall precipitation put them out) are now suppressed without being able to burn nearly as much under the milder conditions. If fire suppression is directly eliminating more low-severity fire, such as by preventing fire under mild condition, this would make the proportion of high severity fire greater even as the amount of high-severity fire is held constant. The direct effects of fire suppression in reducing low severity fire and causing the proportion of high-severity fire to increase needs to be discussed in the yellow pine/mixed conifer NRV.

The fire severity section states that, according to Leiberg, eight percent of Sierran forests had "total destruction" in a 100 year period prior to fire suppression. As mentioned earlier, the precise amount of high-severity fire was shown in the map prepared by Leiberg (1902)(Figure 3). The map clearly shows a high percent (far higher than 8 percent) of the area burned at high severity (75% tree mortality by volume or about 85% mortality by basal area). The map is reproduced in the Chaparral NRV (Figure 3). Again, not summarizing the information from this map is a key omission from the yellow pine/mixed conifer NRV.

The yellow pine/mixed conifer NRV also says that most of the fires Leiberg visited had taken place in upper elevation mixed conifer and red fir forests. However, from the Leiberg map and text of the report, it is clear that much or most of the burned area was not upper elevation forests, but more mid-elevation forests. In this regard, it is important to note that Leiberg used "red fir" to refer to Douglas-fir, a mid-elevation species. This may have caused confusion by suggesting that more fire occurred in red fir than actually occurred in red fir.

Another clarification needed in the yellow pine/mixed conifer NRV has to do with the interpretation of the findings of Beaty and Taylor (2001). The fire severity section cites Leiberg to say that 1850-1900 had more destructive fire, thereby suggesting that the findings of Beaty and Taylor relating to this time period include an unnatural human influence. But, as discussed earlier, Leiberg specifically states that most of the fires he mapped from 1800-1890 were from prior to 1850. Moreover, as mentioned in Box 1, fuel loads after settlement were obviously sufficient to support high-severity fire, including in unlogged areas, which much of the high-severity burn mapping by Leiberg and coworkers was. The study area of Beaty and Taylor (as well as Bekker and Taylor) was not logged. Thus, logging slash does not explain the findings. Second, the yellow pine/mixed conifer NRV states that severity classes in Beaty and Taylor (2001) were assigned based on numbers of emergent trees (i.e., how "single-aged" was the stand) and that these are rare in the Sierra Nevada. However, the classes were not assigned based on "single-aged" stands regenerating from fire, but rather the number of emergent trees that survived fire. High severity was 10 or fewer of these trees per ha, and moderate severity was 10-20 emergent trees/ha. These are very low rates of survival, so they represent greater levels of severity than often used for the high- and moderate-severity categories.

The fire severity section points out that very few studies have found even-aged stands such as found in chaparral and closed cone pine ecosystems, that would be indicative of high-severity fire (no studies that have attempted to locate single-aged stands are mentioned). However, forests in the Sierra Nevada differ dramatically in their population biology than chaparral and closed cone pine forests. In these vegetation types, the plants that will dominate the site all establish in the first year or two after fire, hence they are single-aged. In contrast, Sierran forests (except knobcone pine, which is rare) are not single-aged because reproduction, though highest right after fire, continues to occur in the periods between fires. In fact, a major reason why there are concerns about fire suppression is because of recruitment of young, shade tolerant trees in long-unburned stands causing forests to become denser, at least in formerly logged areas (Naficy et al. (2010). In addition, as mentioned in the previous paragraph, some large, emergent trees may survive severe fire. This adds to the age diversity of stands. Given the recruitment and survival processes in these forests, single-aged stands do not occur and are not to be expected. Their absence is not evidence of the absence of high-severity fire, however. The vegetation that is evidence of high severity fire would be complex early successional vegetation composed of chaparral and young trees. There is ample evidence for the historic occurrence of such vegetation as described in the chaparral NRV (see also Leiberg 1902, Show and Kotok 1924, Wilken 1967, Nagel and Taylor 2005). There is also ample evidence that this chaparral has decreased because of fire suppression. Many areas that burned historically at high-severity now support mature forests. Thus, evidence for past high-severity fire has been obscured. For example, on contemporary imagery, patches of historic high severity fire are not visible. It is necessary to use historic imagery to identify early successional vegetation associated with historic high-severity fire. The studies that have used early aerial photography have found large amounts of high-severity fire at landscape scales (e.g., Russell et al. 1998, Beaty and Taylor 2001, Bekker and Taylor 2001, Hessburg et al. 2007 [in the dry Cascades]). In contrast, there are no such landscape scale studies that have not found considerable amounts of high-severity fire.

Fire severity in a limited number of fires in Yosemite's Illilouette Valley (e.g., Collins et al. 2010) may be misrepresentative of the mid to upper elevation forests of the Sierra Nevada and southern Cascades. This area was glaciated and consequently has high cover of bare rock. In addition, the Park only lets fires burn when they are within a prescription window (conditions that favor lower fire severity). Because high severity fire and rate of spread may increase dramatically under more extreme conditions, the burn policy may be preventing significant amounts of higher-severity fire. Thus, the fire regime in the Illilouette Valley likely represents only the lower severity portion of the statistical distribution of fire severity that historically occurred in the affected forests.

Estimates of historical and current high-severity fire are the basis for comparing past and present amounts of high-severity fire. Therefore, the lack of any assessment of historical vs. current high-severity rotations in the NRV report is a particularly important omission. In fact, rotation of high-severity fire is probably the most important indicator of fire regimes to include in the assessment, especially given the NRVs emphasis on high-severity fire.

Hanson and Odion (2013) found rotations for high-severity fire from 1984-2010 of 461, 893, and 714 years in western lower montane, western mid-upper montane, and eastern montane forests, respectively (645 years overall). This is longer than rotations estimated by Stephens et al. (240-400 years), or that may be inferred from Leiberg (1902). Even shorter rotations exist from the data presented by Beaty and Taylor (2001) in a landscape of mid-to upper montane forests near Lassen (101-394 years depending on topography), and Bekker and Taylor (2001), also in mid- and upper montane forests in the Lassen area (165-210 years). The high severity rotation for Jeffrey pine forests in Baja was 300 years (Minnich et al. 2000), but these forests are very sparse compared to Sierran forests. In contrast, Scholl and Taylor found a 3,000 ha area of Yosemite with no record of stand-replacing fire for 300-400 years. However, USFS surveys of the landscape in which this forest occurs found an abundance of high-severity fire in forests (USFS 1910-1912), so the 3,000 ha patch studied was not representative of the broader landscape in which it occurred.

Thus, the weight of evidence indicates that creation of complex early successional habitat, including montane chaparral, by high-severity fire, has decreased dramatically due to fire suppression. Moreover, the current rate of high-severity fire does not appear to be increasing.

Hanson and Odion (2013) analyzed all available fire severity data from 1984-2010 over the whole Sierra Nevada and southern Cascades ecoregion and found no trend in proportion, area, or patch size of high-severity fire. The rate of high-severity fire has been lower since 1984 than the estimated historical rate. Specifically, there was no significant trend over this time in high-severity fire proportion in western lower montane ($p = 0.646$), western mid-upper montane ($p = 0.379$), or eastern montane forests since 1984 ($p = 0.087$). There was no trend in annual area of high-severity fire in western lower montane ($p = 1.00$), western mid-upper montane ($p = 0.242$), or eastern montane forests ($p = 0.478$). Nor was there any trend in high-severity fire mean annual patch size ($p = 0.529$), or maximum annual patch size ($p = 0.865$) (Fig. 3a-b). None of the time series were autocorrelated. These results differ from the findings of Miller et al. (2009) and Miller and Safford (2013) because all the fire data from 1984-2010 in the region were included in the analysis by Hanson and Odion (2013) and Hanson and Odion used a map that predated fires to identify forests (Miller et al. (2009) and Miller and Safford (2013) used maps that post-dated fires and the vegetation changed in some areas due to fire, which introduces an artificial trend). Miller et al. (2012) discuss the need to use a pre-burn map in these analyses. The results of Hanson and Odion (2013) showing no trend are consistent with other studies that have found no trends in fire severity in forests of the Pacific States (Schwind et al. 2007, Hanson et al. 2010, Miller et al. 2012, Dillon et al. 2012).

High-severity Patch Size (starting on line 1104)

The NRV needs to do a more complete, statistically appropriate assessment of high-severity patch sizes. A study that involved a very large area that looked at patch sizes of high severity fire in the dry Cascades was done by Hessburg et al. (2007). The area studied by Hessburg et al. (2007) was forested by ponderosa pine and dry mixed conifer forests. Hessburg et al. found high severity patches in excess of 5,000 ha (see Perry et al. 2012). Leiberg (1900) also mentions patch sizes of about 1500 ha for fires in the southern Cascades. The hypothesis of the yellow pine/mixed conifer NRV, that high-severity patches over 100 ha are unnatural, is not based on a complete assessment of possible high-severity patch sizes.

Large high-severity patches are difficult to assess because they are extreme events that occur infrequently and stochastically. Large landscapes need to be analyzed over reasonably long periods of time. However, large patches account for most of the cumulative area that burns at high severity (Williams and Baker 2012). In fact, they may account for over 80 percent of all high severity fire. On the other hand, small patches are dominant in number. Accordingly, it is important to consider the full distribution of patch sizes in evaluating a fire regime. The distribution of high-severity patches is long-tailed (Pareto), and consequently, mean patch size or other measures of central tendency used in the NRV are not particularly meaningful descriptors. In addition, using data such as these that are not normally distributed violates the assumptions of parametric statistics. This is a good example of why statistical distributions rather than central tendencies are commonly compared, rather than central tendencies, in monitoring of environmental conditions (Stoddard et al. 2007).

If patch sizes of contemporary high-severity fires are larger than historical patches, this may not be due to increased fire severity. Larger average size of contemporary patches of high-severity fire may be expected because fire suppression is more effective in stopping fires that are less severe, which are likely to have smaller patches of high-severity fire. Patch sizes of high-severity fire have not been increasing in recent decades (Hanson and Odion 2013).

Fire Size (beginning on line 1130)

The analysis of historical vs. current fire sizes is an apples to oranges comparison because the full perimeters of all past fires, particularly large ones, are not known. In contrast, the full perimeter of contemporary fires is known.

Indicators of conditions in Yellow Pine and Mixed Conifer Forests

The rotation of high severity fire is a fundamental indicator of the condition of these forests. It provides the rate of stand-replacing fire, which will indicate how much successional diversity is being created by fire and whether forests are increasing or decreasing in extent. As discussed above, high-severity fire rotations are longer (less fire) under fire suppression compared to when fires burned freely through forests under a wide range of weather conditions. This means that yellow pine and mixed conifer forests are increasing in extent at the expense of chaparral, aspen, and other early successional vegetation. The yellow pine/mixed conifer NRV does not describe high-severity fire rotations and consequently does not provide a basis for understanding whether the forests are increasing or decreasing.

Forest and Landscape Structure (beginning on line 1983)

This section says that fire did not leave a coarse-grained pattern on the landscape that could be easily mapped. However, the Leiberg (1902) fire severity map shows a coarse-grained landscape pattern. The Leiberg surveys (Leiberg 1902) also mapped chaparral, which is shown as a coarse-grained pattern (Figure 3 of the chaparral NRV). Much of this chaparral was forest that had burned at high-severity as discussed later in this section of the NRV. So, the NRV seems self-contradictory. Of course, a fine-grained pattern of high-severity patches also occurred within contiguous blocks of forest. To provide a systematic assessment of the evidence, the full range of variation in patch size needs to be considered (see section above on patch sizes).

The discussion of LANDFIRE BpS model outputs that begins on line 2071 seems quite consistent with a mixed severity fire regime and thus appears to also contradict the description throughout most of the document of low-moderate severity fire regimes. If 15-20 percent of the landscape was early successional, high-severity fire rotations had to have been much shorter than contemporary high-severity rotations. In fact, the Rapid Assessment Reference Condition Models I have seen on the internet have described the rotation for stand-replacing fire in Jeffrey pine forests and ponderosa pine forests as 200-250 years, consistent with a mixed-severity fire regime that maintained 15-20 percent of the landscape in early successional condition. This rotation length is much shorter (less fire) than current rotations for high-severity fire (see section above on fire severity). Thus, this section also contradicts much of the rest of the NRV document that describes a much smaller role for high-severity fire, and an increase, not decrease, in forest susceptibility to high-severity fire.

The text starting on line 2101 states that fire suppression has "driven" a species dominance shift to fire intolerant trees. However, where it has been studied (n. Rockies), fire suppression alone has not been found to lead to a significant increase in fire intolerant trees. Instead, this was driven by historic logging that opened the forest overstory (Naficy et al. 2010). The SNEP report considered logging to have a bigger effect on Sierran forests than fire suppression. It is common to find unlogged areas away from roads that do not have particularly dense understories. Research is needed in the Sierra Nevada to sort out the relative roles of historic logging and fire suppression in causing the recruitment of shade tolerant trees.

General Forest Structure (beginning on line 2137)

This section quotes a number of observations about forests being open and parklike. It does not review the evidence discussed in Box 1 and the alternative view presented from this evidence. This view is that the forests were not mostly open and parklike because there are many descriptions of dense, dark forests, including by Muir. This information and view discussed in Box 1 needs to be presented to systematically review the evidence on forest structure.

Tree Density (beginning on line 2268)

This section notes that "differences [between current and reconstructed forest density] may be slightly inflated by the inability of reconstruction studies to accurately account for very small trees in the historical period, especially from species that rapidly decay such as the firs." The level that current forest density may be inflated over the reconstructed historical density is unknown, but could be much greater than slight. It is possible that a very high density of small and medium sized firs existed 110 years ago and all the evidence of these trees has decomposed and therefore would not be captured by reconstructions. There is simply no way of knowing past density of smaller trees from current forest conditions.

Conclusions

The rotation of high severity fire, and changes in the abundance of major vegetation types are important indicators of conditions and how they have changed.

Early successional vegetation has decreased markedly and it has been replaced by later-successional forests and plantations. Efforts to further suppress fire and/or its behavior as well as post-fire logging may further reduce complex early successional vegetation (DellaSala et al. 2013).

The loss of early successional vegetation must be weighed against the gain of conifer vegetation, and especially the late successional stage of conifers. Although these changes are related to fire suppression, they may have benefits for a number of species of concern that have declined regionally due to loss of late successional forests from logging (SNEP 1996). The late-successional forests in the Sierra Nevada are important to regionally threatened species like spotted owl, fisher and marten. However, a recent analysis shows that an increase in mixed-severity fire will have a very minor effect on late successional habitat, but will considerably increase habitat for fire-dependent species that appear to be declining with the loss of early successional habitat (Odion and Hanson 2013). Thus, an increase in mixed-severity fire will better balance the needs of biodiversity as a whole. However, this is a difficult proposition for society without better fire proofing of communities, especially as the increase in mixed-severity fire would have to come mainly by allowing more area to burn in wildfires. More wildfire would also help restore low- and moderate-severity fire.

Protection of burned forests from post-fire logging will also help with the provision of complex early successional habitat (DellaSala et al. 2013), and will prevent type conversion to cheatgrass that has been associated with post-fire logging (McGinnis et al. 2010). In contrast, continued suppression of fire or fire behavior will prolong and potentially exacerbate the impacts of fire suppression in moving chaparral, aspen and yellow pine/mixed conifer forests away from historic conditions. Efforts to suppress fire behavior by thinning forests may be detrimental to species such as aspen and black backed woodpeckers (Hutto 2008) that benefit from abundant fire killed trees, as well as species that use dense forests like the fisher (Truex and Zielinski 2013), and spotted owl (Seamons and Gutierrez 2007). Balancing these tradeoffs will be challenging to managers.

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