A Decade of Change in the Sierra Nevada: Conservation Implications

Chad T Hanson, Earth Island Institute, Berkeley, CA, United States

Abstract

The Sierra Nevada mountain range of California, USA is a region of extraordinary biodiversity and is considered critically endangered by WWF. Over the past decade, an elevated level of natural disturbance has occurred, mainly in the form of large wildfires and a prolonged drought. This has created numerous new patches of "snag forest habitat," which benefits many native species. A key question, however, is whether current processes are occurring within the natural range of variability or are exceeding it, and what are the impacts associated with the responses of land managers to these processes? In this chapter, I conclude that the available evidence indicates that Sierra Nevada forests are likely to ecologically benefit from current levels of dynamic natural disturbance processes, and resulting habitat heterogeneity, so long as the rate of high-intensity natural disturbance does not exceed the natural range of variation over ecologically meaningful timescales in a changing climate. However, calls for increased logging, in the form of commercial thinning and post-fire clearcutting, by Forest Service-funded scientists, and politically-motivated attempts to suppress independent forest/fire and climate scientists, presents a clear and present conservation threat to Sierra Nevada forests, especially ponderosa pine and mixed-conifer forests that are the primary target of forest managers and logging companies.

Overview: A dynamic natural disturbance history

The past decade has seen extraordinary levels of dynamic change in the forests of the Sierra Nevada mountains of California, USA. That is, relative to the recent past. Since 2011, tens of millions of trees have died due to drought, and numerous fires over 40,0000 ha and some well over 100,000 ha—have occurred. But are these changes "bad" or unprecedented, as so many people seem to believe? Are widespread natural disturbance processes, at recent levels, a stressor or are they promoting ecological resilience?

In this chapter, I will explore these recent changes within the context of the historical levels of natural disturbance processes, and address whether the evidence suggests the changes are more likely to be ecologically negative or positive, particularly within the mixed-conifer and ponderosa pine (*Pinus ponderosa*) forests that have been most influenced by recent changes. I will also address the impacts of key anthropogenic stressors within this region of world-class biodiversity and ecological value. Notably, the Sierra Nevada forests are considered globally distinctive and critically endangered by the World Wildlife Fund (Ricketts et al., 1999), so they qualify as an imperiled region.

The Sierra Nevada mountains in California, USA, are home to some of the most biodiverse temperate conifer forests in the world, with exceptionally high levels of endemic plants (Ricketts et al., 1999). California has about 7000 native vascular plant species, and approximately half of them occur in the Sierra Nevada, including 400 endemic and 200 rare species. The Sierra Nevada is also home to numerous rare and imperiled birds, such as the California spotted owl (*Strix occidentalis occidentalis*) and black-backed woodpecker (*Picoides arcticus*), and endangered carnivores, such as the Pacific fisher (*Pekania pennanti*) (Bond and Hanson, 2014; Hanson, 2015; Hanson and Chi, 2020).

Historically, prior to fire suppression and logging, mixed-conifer and ponderosa pine forests of the Sierra Nevada were highly heterogeneous due to dynamic ecological disturbance processes like fire, drought, and native beetles. In unlogged forests prior to 1890, for example, "complex early seral forest" habitat (DellaSala et al., 2014), which is created by high-intensity natural disturbance (fire or drought and native beetles) that kills most or all of the canopy trees, comprised 28% of these forest types, while 30% were mid-successional (40–79 years old), and 42% were late-successional/old-growth forests 80 years old or older, according to an extensive stand-age analysis across the mountain range in forests with no logging history (Odion et al., 2014, 2016). Other analyses, using historical field data from early U.S. government forest surveys, indicate that complex early seral forest (CESF) comprised approximately 20–30% of these forests at any given time, and depending on the subset of the region (Hanson and Odion, 2016a, b; Baker and Hanson, 2017). At the watershed scale, CESF sometimes comprised over 50% of the forest, especially at middle elevations dominated by white fir (*Abies concolor*) (Beaty and Taylor, 2001; Bekker and Taylor, 2001).

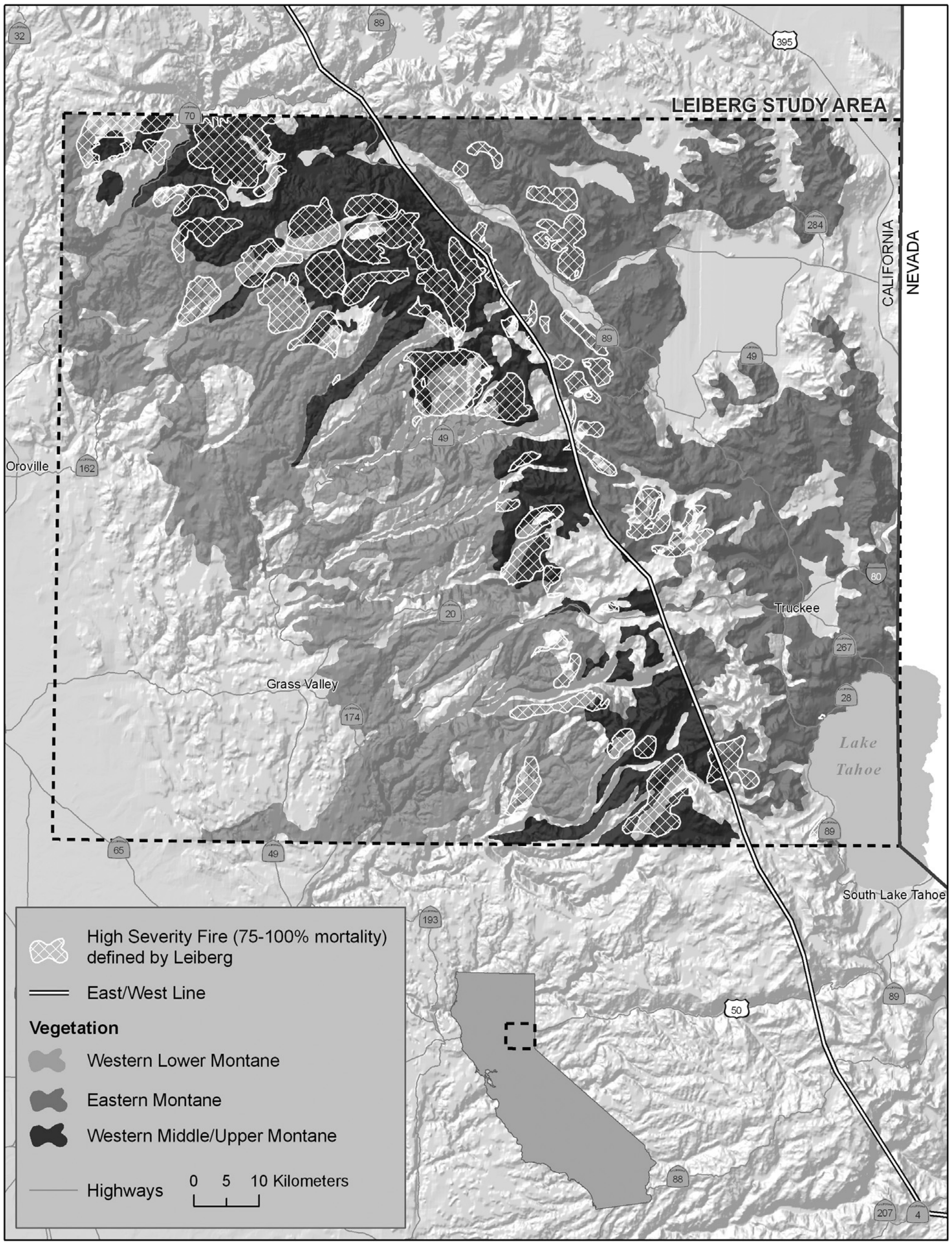

Fig. 1 Map derived from a U.S. Geological Survey multi-year field mapping effort in the northern Sierra Nevada during the late 1800s (Leiberg, 1902), showing high-intensity fire patches thousands, and in some cases tens of thousands, of of hectares in size.

Historically, wildland fires were often small, as most forest fires are now, but during drought years individual fires could be very large, sometimes spanning vast areas as large or larger than recent fires (Bekker and Taylor, 2010; Caprio, 2016; Baker and Hanson, 2017). And, prior to fire suppression and logging, fires were comprised primarily of low/moderate-intensity effects, where most mature and many small trees survived, though high-intensity fire patches were always a substantial component of fire complexes. These high-intensity fire patches were often small but, in large drought-year fires, individual high-intensity patches frequently reached hundreds or thousands of hectares, with numerous patches reaching 8000–20,000 ha or larger (Leiberg, 1902; Baker, 2014; DellaSala and Hanson, 2019; see also Fig. 1).

Historical mixed-conifer and ponderosa pine forests of the Sierra Nevada were also highly heterogeneous in terms of stand structure and forest density. They ranged from open forests, which comprised a minor portion of these forest types, to forests with hundreds, or even thousands, of trees per hectare (Baker, 2014; Hanson and Odion, 2016a, b; Baker and Hanson, 2017). Patches of native shrubs, or montane chaparral, comprised 40%, 29%, and 75% of the overall area in mixed-conifer/fir, mixed-conifer/pine, and ponderosa pine forests, respectively; in mature forests, in particular, these forests had 34% shrub cover on average, ranging from

Fig. 2 Old forest that recently experienced low-intensity surface fire in the Star fire of 2001, Sierra Nevada.

6% to 80% (Hanson and Odion, 2016a). Conifer seedlings/saplings had an average density of 837 per hectare, ranging from 44 per hectare to 5466 per hectare (Hanson and Odion, 2016a). Some previous studies had omitted most of the historical tree density data, including extensive data on the density of oaks, and small conifers. When these omitted data were included, it was revealed that historical mixed-conifer forests were 7 times denser than previously reported, in trees per hectare, and historical ponderosa pine forests were 17 times denser than previously reported (Baker et al., 2018). Figs. 2 and 3A and B show the effects of forests experiencing low and high intensity fires.

Therefore, prior to fire suppression and logging, the lower/middle-elevation forest types of the Sierra Nevada were extremely variable, with a complex mix of mature/old forest patches—very dense in some places and open to moderately dense in others, CESF patches of widely-varying sizes, and many mid-successional forests in between. Such tremendous heterogeneity is associated with high levels of beta diversity (DellaSala and Hanson, 2015; DellaSala et al., 2017), providing ample habitat not only for species that depend, at least in part, on dense, old forest but also for species that need CESF patches dominated by a high abundance of snags (standing dead trees), downed logs, montane chaparral, wildflowers, and naturally-regenerating young conifers and hardwoods. These include small mammals, some raptors, woodpeckers and secondary cavity-nesters, shrub-nesting birds, many flycatchers, bats, numerous ungulates and carnivores, and a dizzying array of invertebrates (DellaSala and Hanson, 2015; Hanson, 2021a).

Over the past decade in particular, natural disturbance processes, influenced by weather, climate, and climate-change (Bradley et al., 2016; Koontz et al., 2021), have seen a marked increase in Sierra Nevada forests, as tens of millions of new snags were created by an intense drought cycle during 2012–2017, and several very large mixed-intensity wildland fires occurred, including the 104,178-ha Rim fire of 2013, the 153,804-ha Creek fire of 2020, and the 389,837-ha Dixie fire of 2021, among several others. Most trees survived in the heavily drought-affected areas (Byer and Jin, 2017), and even the largest fires are dominated by low/moderate-intensity fire effects, where the majority of mature trees and many small trees survive (Hanson, 2018, 2021b). In Sierra Nevada forests, CESF habitat remains spatially less common now than it was historically, prior to fire suppression and logging (Hanson and Chi, 2020; Hanson, 2021a). Nevertheless, recent natural disturbance processes, and associated recruitment of snags and patches of snag-forest, have substantially increased habitat heterogeneity at multiple spatial scales, bringing Sierra Nevada forests closer to the historical mix of CESF and mature forests (Baker et al., 2021).

Complex early seral forest habitat: An underappreciated ecological treasure

Merely understanding that CESF habitat is not currently in excess of historical levels in Sierra Nevada forests may not mean much to some readers without some background on the ecological value of this unique habitat. There are now quite literally hundreds of peer-reviewed studies that have been published on the ecological importance of this habitat, and that body of research is concisely summarized, synthesized, and cited in DellaSala and Hanson (2015) and Hanson (2021a).

In short, the rich and complex habitat features in CESF, including snags, downed logs, flowering shrubs and wildflowers, and naturally-regenerating young trees, provides food and homes for an impressive diversity and abundance of native species. Wood-boring beetles and bark beetles depend on fire-killed and drought-weakened/killed trees, respectively, in order to reproduce. Numerous woodpecker species depend on the larvae of the beetles as their primary food source, as they also depend on snags to

Fig. 3 Complex early seral forest habitat, naturally regenerating after high-intensity fire in the Sierra Nevada, more than 300 m from the nearest live, surviving conifer.

excavate new nest cavities each year, since snags are softer than live trees. Previous woodpecker cavities are then used by dozens of native bird and small mammal species that need tree cavities to raise their young but cannot create their own nest/den cavities, such as bluebirds (*Sialia mexicana and Sialia currucoides*), nuthatches, chipmunks, flying squirrels, and many others. Flying insects (e.g., many pollinators) are attracted to the flowering shrubs and wildflowers in CESF, providing food for flycatching birds and bats. Small mammals den in the shrub patches and downed logs, in turn providing food for hawks and owls, including the imperiled California spotted owl, which preferentially forages in CESF (Bond et al., 2009). Imperiled and endangered carnivores, such as the Pacific fisher, hunt for their small mammal prey in CESF, and ungulates browse on the nutrient-rich native understory plant growth, while wolves and grizzly bears benefit from the enhanced ungulate prey availability. Black bears get fat on the abundant berry-producing plants growing in CESF in advance of winter hibernation. CESF, created by either high-intensity fire or high-intensity drought effects that kill most or all trees in patches, typically has levels of native biodiversity and wildlife abundance that are comparable to old forest, and many native species are primarily associated with CESF (DellaSala and Hanson, 2015; Hanson, 2021a).

Giant sequoias and fire: Hope amidst the ashes

Given recent large fires, there has been a growing and understandable concern about groves of giant sequoias (*Sequoiadendron giganteum*) in the Sierra Nevada, especially since only about 70 naturally-occurring groves remain in the world (depending on how groves are mapped and counted by various entities/agencies)—all of them in the central and southern Sierra Nevada.

A recent unpublished U.S. government report estimated that 75,580 mature (those over 122 cm in diameter) giant sequoias remain in the Sierra Nevada, and further estimated that 10–14% were killed in the 70,487-ha Castle lightning fire of 2020, which burned through several sequoia groves, mostly in the Giant Sequoia National Monument (https://www.nps.gov/articles/000/preliminary-estimates-of-sequoia-mortality-in-the-2020-castle-fire.htm). Another unpublished U.S. government report estimated that an additional 3–5% of mature giant sequoias were killed in the Windy lightning fire (39,485 ha) and KNP Complex lightning fire (35,752 ha) of 2021 in the southern Sierra Nevada (https://www.nps.gov/articles/000/2021-fire-season-impacts-to-giant-sequoias.htm). Though these estimates may seem alarming, there is good reason for hope.

First, these estimates of mature giant sequoia mortality are, fortunately, likely to be overstated. While a minor percentage of mature sequoias are killed in any large mixed-intensity fire, giant sequoias are among the most fire-resistant conifer species on the planet, and many sequoias that initially appear dead are not. This is so in part because of their thick bark. In addition, even when a fire has killed nearly all of the foliage in a giant sequoia's crown, sequoias have evolved mechanisms to produce new green foliage in the summer of the first year following the fire, such that even with sequoias that have had 90% of their crowns killed by fire, survival is 100% (Stephens and Finney, 2002).

Perhaps more importantly, giant sequoias depend not merely on fire, but on moderate/high-intensity fire in particular, to effectively reproduce, since these higher-intensity fire patches facilitate release of seeds from sequoia cones, consume the thick duff and litter on the forest floor to create a nutrient-rich bed of mineral ash, and kill many or most overstory trees to create sunnier conditions—all of which allows sequoia seedlings to germinate, establish, and thrive (Stephenson, 1994). Low-intensity fire does not create this combination of conditions, and does not facilitate meaningful reproduction, while moderate-intensity fire facilitates intermediate levels of reproduction, and high-intensity fire patches (which necessarily will kill many if not most mature sequoias) facilitate by far the highest levels of reproduction (Meyer and Safford, 2011). This is profoundly important, since the key threat to giant sequoias over the past century of fire suppression has been a "massive failure" of reproduction (Stephenson, 1994). In essence, mature sequoias have been slowing dying off for decades—without being replaced by new, young sequoias—due to the exclusion of natural mixed-intensity fires from the groves. For every mature sequoia that may be killed in a high-intensity fire patch, therefore, hundreds of new giant sequoias grow amidst the ashes, where previously reproduction was glaringly and dangerously absent.

I witnessed this firsthand in the Nelder Grove on Sierra National Forest in the southern Sierra Nevada, where the Railroad fire swept through the grove in 2017, killing approximately three dozen mature giant sequoias—mostly in one large (over 500 ha) high-intensity fire patch—while the fire burned at low/moderate intensities elsewhere in the Nelder grove. In the low-intensity fire areas, giant sequoia reproduction is non-existent, except at the very edges of moderate-intensity fire patches, where sequoia reproduction is occurring to some degree, and growing slowly, but is outnumbered by regeneration of other conifer species. In stark contrast, within the large high-intensity fire patch giant sequoia reproduction is simply extraordinary, with at least several hundred giant sequoia seedlings and saplings growing per hectare (and, in some areas, thousands per hectare, see Fig. 4). In this large high-intensity fire patch, nearly all of the natural post-fire conifer regeneration is comprised of giant sequoias, and they are growing much faster and taller than in the low/moderate-intensity fire areas in the grove.

The time-since-fire conundrum

One of the most persistent misconceptions about forests and fire in the Sierra Nevada is the notion that, due to "fuel accumulation" from many decades of fire suppression, much of the forested landscape is "overgrown" with too much biomass of live and dead trees, and, as a result, forests are ostensibly burning significantly more intensely in such areas. Based on this assumption, land managers continue ever more aggressive suppression of wildland fires, thinking that fires will have mostly high-severity effects if they are allowed to burn, which undermines the ecological goal of expanding managed wildfires (also known as "prescribed natural fires") to restore fire to the landscape. Moreover, based on this narrative and its associated assumptions, land managers are increasingly promoting commercial logging, especially "commercial thinning," under the rubric of "fuel reduction," claiming that such management must be expanded as an alternative to natural wildfires in fire-excluded forests.

Fig. 4 Abundant natural post-fire giant sequoia regeneration in a large high-intensity fire patch from the Railroad fire of 2017, Nelder Grove.

But are these assumptions consistent with the data? Interestingly, this question has been studied quite extensively in numerous articles, and the results have overwhelmingly contradicted the prevailing assumptions about time-since-fire and "fuel accumulation." For example, time-since-fire has specifically been investigated multiple times, and researchers have typically found that the most long-unburned forests—including those than have not burned in over 75 years or more than a century—experience mostly low/moderate-intensity fire effects when wildland fires occur, and such forests do not tend to burn more intensely than forests that have had fire more recently (Odion et al., 2004; Odion and Hanson, 2008; Odion et al., 2010; Miller et al., 2012; van Wagtendonk et al., 2012). In seemingly counter-intuitive fashion, long-unburned forests often burn less intensely (Odion et al., 2010; Miller et al., 2012). Relatedly, denser, mature/old forests with more biomass do not tend to burn more intensely than more open forests and, in fact, often experience lower fire intensities (Lesmeister et al., 2019; Dunn et al., 2020; Meigs et al., 2020).

Nor do forests with higher pre-fire densities of snags tend to burn more intensely, or spread more quickly, when wildfires occur, contrary to popular belief (Hart et al., 2015; Meigs et al., 2016; Hart and Preston, 2020; Hanson, 2021b). Such forests may often burn less intensely (Meigs et al., 2016).

How can this be? While long-unburned forests, and other dense forests, do indeed tend to have more biomass, they also have more cooling shade from higher canopy cover, and that keeps the forest floor moist during fire season, while the denser tree cover acts as a wind break, buffering and slowing the gusts that drive flames during a fire. Snags have little to carry flames, since dead needles and twigs quickly fall and decay into soil. And, when snags fall, the large downed logs they become soak up enormous amounts of moisture, and can hold 25 times more water per unit of volume area than the surrounding soil—even in a drought year (Amaranthus et al., 1989)—thus acting more like giant sponges than "fuel."

The lesson here is that we can, and should, allow more natural lightning strikes to burn for habitat benefit, and to facilitate ecological restoration of mixed-intensity fire, including in dense, long-unburned forests, and in forests that have abundant snags from recent drought conditions.

The ongoing threat from logging

Based on the scientifically discredited "fuel accumulation" notion, land managers are currently moving forward aggressively with logging projects on federal public forestlands, and state and private forestlands, predicated on the assertion that commercial "thinning" and post-fire logging equate to effective "fuel reduction" and fire management approaches (Fig. 5A and B). The typical commercial "thinning" project kills and removes upwards of 70% of the trees in a given stand, including many mature and old-growth trees up to 76 cm in diameter, and in many cases up to 102 cm in diameter (USFS, 2004, 2020). Large-scale and widespread clearcutting of ecologically vital post-fire habitat is also occurring on public and private forestlands in the Sierra Nevada under the rubric of "fuel reduction."

This management approach not only stubbornly ignores the abundant and accumulating research disproving the "fuel accumulation" management assumptions, but also the growing body of scientific research indicating that forest fires are driven primarily by weather and climate factors, and climate change (Bradley et al., 2016), and that removing live or dead trees from forests—through either "thinning" or post-disturbance logging—does not tend to effectively curb weather/climate-driven fires, and such management is often associated with higher, not lower, fire intensity (Cruz et al., 2014; Bradley et al., 2016; Hanson, 2021a, b). The "fuel reduction" logging approach also ignores the climate impacts of this management, including the fact that commercial thinning emits three times more CO_2 into the atmosphere per hectare than wildfire alone, given the extremely low levels of tree consumption that actually occur in wildfires, and the high levels of carbon removal that occur in commercial thinning operations (Campbell et al., 2012). Further, the fuel-reduction logging approach tends to downplay the severe adverse impacts that both commercial thinning and post-fire logging have on many rare and imperiled wildlife species, including the California spotted owl (Stephens et al., 2014; Hanson et al., 2018), the black-backed woodpecker (Hanson and North, 2008; Hanson and Chi, 2020), the endangered Pacific fisher (Hanson, 2015), and numerous, shrub-nesting and cavity-nesting birds that are associated with CESF habitat and have been declining over time or which have become so rare that no population trend can be discerned (Hanson, 2014).

A troubling scientific omission

In 2021, a trio of articles was published in the same issue of the journal, *Ecological Applications*, by a group of scientists funded by the U.S. Forest Service, an agency that, under current laws, engages in commercial logging activities on U.S. public lands, selling public trees to private logging companies and keeping the revenue for its budget. The central article, Hagmann et al. (2021), presented itself as a scientific review, and included a few tables (Tables 3 through 6 in Hagmann et al.) listing a series of studies published by independent forest/fire ecologists over the past two decades. These studies by independent scientists provided abundant evidence that historical forests were much more variable in density than previously believed or reported, and were denser overall and had far more mixed- and high-intensity fire than was assumed in the past. In these same tables, Hagmann et al. (2021) juxtaposed these studies with a list of response articles primarily by Forest Service-funded scientists. Based on this juxtaposition, Hagmann et al. (2021) then reported that the list of studies by independent scientists had been criticized and dismissed by the listed response articles from Forest Service-funded scientists, and that two decades of research by these independent scientists could, therefore, be ignored.

(A)

(B)

Fig. 5 (A) Commercial "thinning" on the Sierra National Forest, and (B) post-fire logging on the Stanislaus National Forest.

On this basis, the other two articles in the trio that were published simultaneously in *Ecological Applications*, Prichard et al. (2021) and Hessburg et al. (2021), relied on this central assertion by Hagmann et al. (2021) to claim that the matter has now been settled, scientifically, and that there is no remaining credible dispute about the evidence. All three articles in the *Ecological Applications* trio promoted an increase in commercial logging—including both commercial thinning and post-fire logging—ostensibly to restore forests of the Sierra Nevada and elsewhere in the western U.S. and to curb wildfires. Aside from the questionable nature of the premise that increased logging is an effective wildfire management approach, as discussed above, the Hagmann et al. (2021) article (and by extension the Prichard et al. and Hessburg et al. articles) committed a startling scientific omission. Hagmann et al. neglected to mention the existence of a long list of published reply articles by the independent scientists who soundly refuted and rebutted the response articles that promoted logging. These reply articles, among other things, generally: (a) pointed out that the response articles did not even challenge the central conclusions of the original studies by the independent scientists; and (b) refuted and discredited the largely tangential criticisms that were raised in the response articles.

The reply articles by the independent scientists, pertaining to forests of the Sierra Nevada, include what is likely the most extensively accuracy-checked and cross-validated body of scientific evidence in the history of the field of forest and fire ecology. Notably, this "included 20 modern validations with plot data, 47 specific historical cross-validations in small areas, six large areas with general cross-validations, 99 corroborating observations from scientific studies, and general corroboration from seven paleo-reconstructions" (Baker et al., 2018). None of this massive body of evidence is disputed by the Forest Service scientists

(Baker et al., 2018). Any lingering methodological critiques by the Forest Service scientists have been rebutted and discredited (e.g., Baker and Williams, 2018, 2019), with no further substantive criticisms or comebacks subsequently raised by the Forest Service scientists. Yet a reader of the trio of articles in *Ecological Applications* would be completely unaware of the enormous and undisputed body of scientific evidence squarely refuting the conclusions, and recommendations for increased commercial logging, in Hagmann et al. (2021), Prichard et al. (2021), and Hessburg et al. (2021).

A scientific omission of this magnitude and consequence, especially in a purported review article, is unprecedented in the field of forest and fire ecology. Making matters worse, lead authors of the trio of *Ecological Applications* articles engaged the media, finding a news outlet that willingly participated in an attack on the entire group of independent scientists, based on the false narrative presented in the trio of articles by the Forest Service-funded scientists (Hanson, 2021c). Notably, hundreds of independent scientists (those whose funding is not dependent upon agencies or entities that financially benefit from logging), led by the top U.S. ecologists and climate scientists, have strongly refuted the arguments made by the few dozen scientists who authored the trio of articles in *Ecological Applications*, noting that logging, including "thinning," is not an effective fire management approach in the face of increasingly weather and climate-driven fires, and that such logging can often increase fire intensity, while exacerbating climate change (Moomaw et al., 2020, 2021).

Under these circumstances, government-subsidized misinformation, censorship of scientific evidence, and retaliation against independent scientists must be included among the conservation threats to forest ecosystems of the Sierra Nevada (Lee et al., 2021).

Conclusions

The extraordinary biodiversity of the Sierra Nevada is currently benefitting from dynamic natural disturbance processes, and resulting habitat heterogeneity, which have been elevated in particular over the past decade. In a changing climate, so long as the rate of high-intensity natural disturbance does not exceed the natural range of variation, over ecologically meaningful timescales (Baker, 2015), such processes can be expected to continue to provide benefits to the rich ecology of the Sierra Nevada (Baker et al., 2021; Hanson, 2021a). However, calls for increased logging, in the form of commercial thinning and post-fire clearcutting, and politically-motivated attempts to suppress independent forest/fire and climate scientists, present a clear and present conservation threat to Sierra Nevada forests, especially ponderosa pine and mixed-conifer forests that are the primary target of forest managers and logging companies.

References

Amaranthus MP, Parrish DS, and Perry DA (1989) Decaying logs as moisture reservoirs after drought and wildfire. In: Alexander EB (ed.) *Proceedings of Watershed '89: Conference on the Stewardship of Soil, Air, and Water Resources. USDA-FS Alaska Region. RIO-MB-77* 191–194.

Baker WL (2014) Historical forest structure and fire in Sierran mixed-conifer forests reconstructed from general land office survey data. *Ecosphere* 5: Article 79.

Baker WL (2015) Are high-severity fires burning at much higher rates recently than historically in dry-forest landscapes of the western USA? *PLoS One* 10: Article e0136147.

Baker WL and Hanson CT (2017) Improving the use of early timber inventories in reconstructing historical dry forests and fire in the western United States. *Ecosphere* 8: Article e01935.

Baker WL and Williams MA (2018) Land surveys show regional variability of historical fire regimes and dry forest structure of the western United States. *Ecological Applications* 28: 284–290.

Baker WL and Williams MA (2019) Estimating historical forest density from land-survey data: Response. *Ecological Applications* 29: Article e02017.

Baker WL, Hanson CT, and Williams MA (2018) Improving the use of early timber inventories in reconstructing historical dry forests and fire in the western United States: Reply. *Ecosphere* 9: Article e02325.

Baker WL, Hanson CT, and DellaSala DA (2021) *Nature-based solutions to disturbance management for restoration and climate- change adaptation in dry forests of the western USA*. In review.

Beaty RM and Taylor AH (2001) Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, Southern Cascades, USA. *Journal of Biogeography* 28: 955–966.

Bekker MF and Taylor AH (2001) Gradient analysis of fire regimes in montane forests of the southern Cascade range, Thousand Lakes Wilderness, California, USA. *Plant Ecology* 155: 15–28.

Bekker MF and Taylor AH (2010) Fire disturbance, forest structure, and stand dynamics in montane forests of the Southern Cascades, Thousand Lakes Wilderness, California, USA. *Ecoscience* 17: 59–72.

Bond ML and Hanson CT (2014) *Petition to List the California Spotted Owl (*Strix occidentalis occidentalis*) as Threatened or Endangered under the Federal Endangered Species Act*. Big Bear City, CA, USA: John Muir Project of Earth Island Institute.

Bond ML, Lee DE, Siegel RB, and Ward JP (2009) Habitat use and selection by California spot- ted owls in a postfire landscape. *Journal of Wildlife Management* 73: 1116–1124.

Bradley CM, Hanson CT, and DellaSala DA (2016) Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western USA? *Ecosphere* 7: article e01492.

Byer S and Jin Y (2017) Detecting drought-induced tree mortality in Sierra Nevada forests with time series of satellite data. *Remote Sensing* 9: article 929.

Campbell JL, Harmon ME, and Mitchell SR (2012) Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions? *Frontiers in Ecology and Environment* 10: 83–90.

Caprio AC (2016) A historical perspective on large fires in the southern Sierra Nevada: Rare or everyday events? In: *Association for Fire Ecology Annual Meeting* . November 2016.

Cruz MG, Alexander ME, and Dam JE (2014) Using modeled surface and crown fire behavior characteristics to evaluate fuel treatment effectiveness: A caution. *Forest Science* 60: 1000–1004.

DellaSala DA and Hanson CT (eds.) (2015) *The Ecological Importance of Mixed-Severity Fires: Nature's Phoenix*. Waltham, MA, USA: Elsevier Inc.

DellaSala DA and Hanson CT (2019) Are wildland fires increasing large patches of complex early seral forest habitat? *Diversity* 11: Article 157.

DellaSala DA, Bond ML, Hanson CT, Hutto RL, and Odion DC (2014) Complex early seral forests of the Sierra Nevada: What are they and how can they be managed for ecological integrity? *Natural Areas Journal* 34: 310–324.

DellaSala DA, Hutto RL, Hanson CT, Bond ML, Ingalsbee T, Odion D, and Baker WL (2017) Accomodating mixed-severity fire to restore and maintain ecosystem integrity with a focus on the Sierra Nevada of California, USA. *Fire Ecology* 13: 148–171.

Dunn CJ, et al. (2020) How does tree regeneration respond to mixed-severity fire in the western Oregon Cascades, USA? *Ecosphere* 11: Article e03003.

Hagmann RK, et al. (2021) Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests. *Ecological Applications*. https://doi.org/10.1002/eap.2431.

Hanson CT (2014) Conservation concerns for Sierra Nevada birds associated with high-severity fire. *Western Birds* 45: 204–212.

Hanson CT (2015) Use of higher-severity fire areas by female Pacific fishers on the Kern Plateau, Sierra Nevada, California, USA. *The Wildlife Society Bulletin* 39: 497–502.

Hanson CT (2018) Landscape heterogeneity following high-severity fire in California's forests. *Wildlife Society Bulletin* 42: 264–271.

Hanson CT (2021a) *Smokescreen: Debunking Wildfire Myths to Save Our Forests and Our Climate*. Lexington, KY: University Press Kentucky.

Hanson CT (2021b) Is "fuel reduction" justified as fire management in spotted owl habitat? *Birds* 2: 395–403.

Hanson CT (2021c) The latest logging industry smokescreen. *CounterPunch* October 29, 2021. https://www.counterpunch.org/2021/10/29/the-latest-logging-industry-smokescreen/.

Hanson CT and Chi TY (2020) Black-backed woodpecker nest density in the Sierra Nevada. *California. Diversity* 12: Article 364.

Hanson CT and North MP (2008) Postfire woodpecker foraging in salvage-logged and unlogged forests of the Sierra Nevada. *The Condor* 110: 777–782.

Hanson CT and Odion DC (2016a) Historical forest conditions within the range of the Pacific fisher and spotted owl in the central and southern Sierra Nevada, California, USA. *Natural Areas Journal* 36: 8–19.

Hanson CT and Odion DC (2016b) A response to Collins, Miller, and Stephens. *Natural Areas Journal* 36: 229–233.

Hanson CT, Bond ML, and Lee DE (2018) Effects of post-fire logging on California spotted owl occupancy. *Nature Conservation* 24: 93–105.

Hart SJ and Preston DL (2020) Fire weather drives daily area burned and observations of fire behavior in mountain pine beetle affected landscapes. *Environmental Research Letters* 15: Article 054007.

Hart SJ, et al. (2015) Area burned in the western United States is unaffected by recent mountain pine beetle outbreaks. *Proceedings of the National Academy of Sciences of the USA* 112: 4375–4380.

Hessburg PF, Prichard SJ, Hagmann RK, Povak NA, and Lake FK (2021) Wildfire and climate change adaptation of western North American forests: A case for intentional management. *Ecological Applications*. https://doi.org/10.1002/eap.2432.

Koontz MJ, Latimer AM, Mortenson LA, Fettig CJ, and North MP (2021) Cross-scale interaction of host-tree size and climatic water deficit governs bark beetle-induced tree mortality. Nature. *Communications* 12: Article 129.

Lee DE, Bond ML, and Hanson CT (2021) When scientists are attacked: strategies for dissident scientists and whistleblowers. In: DellaSala DA (ed.) *Conservation Science & Policy for a Planet in Peril: Speaking Truth to Power*. Boston: Elsevier.

Leiberg JB (1902) Forest Conditions in the Northern Sierra Nevada, California. In: Professional Paper no. 8, Washington, D.C.: U.S. Geological Survey.

Lesmeister DB, Sovern SG, Davis RJ, Bell DM, Gregory MJ, and Vogeler JC (2019) Mixed-severity wildfire and habitat of an old-forest obligate. *Ecosphere* 10: Article e02696.

Meigs GW, et al. (2016) Do insect outbreaks reduce the severity of subsequent forest fires? *Environmental Research Letters* 11: Article 045008.

Meigs GW, et al. (2020) Influence of topography and fuels on fire refugia probability under varying fire weather in forests of the US Pacific Northwest. *Canadian Journal of Forest Research* 50: 636–647.

Meyer MD and Safford HD (2011) Giant sequoia regeneration in groves exposed to wildfire and retention harvest. *Fire Ecology* 7: 2–16.

Miller JD, Skinner CN, Safford HD, Knapp EE, and Ramirez CM (2012) Trends and causes of severity, size, and number of fires in northwestern California, USA. *Ecological Applications* 22: 184–203.

Moomaw WR, et al. (2020) Scientists Concerned about Climate and Biodiversity Impact of Logging. https://johnmuirproject.org/2020/05/breaking-news-over-200-top-u-s-climate-and-forest-scientists-urge-congress-protect-forests-to-mitigate-climate-crisis/.

Moomaw WR, et al. (2021) Open Letter to President Biden and Members of Congress from Scientists: It is essential to Remove Climate-Harming Logging and Fossil Fuel Provisions from Reconciliation and Infrastructure Bills. https://bit.ly/3BFtlAg.

Odion DC and Hanson CT (2008) Fire severity in the Sierra Nevada revisited: Conclusions robust to further analysis. *Ecosystems* 11: 12–15.

Odion DC, et al. (2004) Patterns of fire severity and forest conditions in the Klamath Mountains, northwestern California. *Conservation Biology* 18: 927–936.

Odion DC, Moritz MA, and DellaSala DA (2010) Alternative community states maintained by fire in the Klamath Mountains, USA. *Journal of Ecology* 98: 96–105.

Odion DC, Hanson CT, Arsenault A, Baker WL, DellaSala DA, Hutto RL, Klenner W, Moritz MA, Sherriff RL, Veblen TT, and Williams MA (2014) Examining historical and current mixed-severity fire regimes in ponderosa pine and mixed-conifer forests of western North America. *PLoS One* 9: e87852.

Odion DC, Hanson CT, Baker WL, DellaSala DA, and Williams MA (2016) Areas of agreement and disagreement regarding ponderosa pine and mixed conifer forest fire regimes: A dialogue with Stevens et al. *PLoS ONE* 11: e0154579.

Prichard SJ, et al. (2021) Adapting western US forests to wild-fires and climate change: 10 key questions. *Ecological Applications*. https://doi.org/10.1002/eap.2433.

Ricketts T, Dinerstein E, Olson D, Loucks C, Eichbaum W, DellaSala D, Kavanagh K, Hedao P, Hurley P, Carney K, Abell R, and Walters S (1999) *A Conservation Assessment of the Terrestrial Ecoregions of North America*. Washington, D.C., USA: Island Press.

Stephens SL and Finney MA (2002) Prescribed fire mortality of Sierra Nevada mixed conifer tree species: Effects of crown damage and forest floor combustion. *Forest Ecology and Management* 162: 261–271.

Stephens SL, et al. (2014) California spotted owl, songbird, and small mammal responses to landscape fuel treatments. *BioScience* 64: 893–906.

Stephenson NL (1994) Long-term dynamics of giant sequoia populations: implications for managing a pioneer species. In: *Aune PS, technical coordinator. The symposium on giant sequoias: their place in the ecosystem and society. USDA Forest Service Pacific Southwest Research Station General Technical Report PSW-GTR-151,* Albany, California, USA 56–63.

USFS (2004) *Sierra Nevada Forest Plan Amendment, Final Environmental Impact Statement and Record of Decision; Pacific Southwest Region*. Vallejo, CA, USA: U.S. Forest Service.

USFS (2020) *SERAL Project Scoping Notice*. Sonora, CA: Stanislaus National Forest.

van Wagtendonk JW, van Wagtendonk KA, and Thode AE (2012) Factors associated with the severity of intersecting fires in Yosemite National Park, California, USA. *Fire Ecology* 8: 11–32.