



COMMENT

Improving the use of early timber inventories in reconstructing historical dry forests and fire in the western United States: Comment

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Knowledge of historical forest conditions and disturbance regimes improves our understanding of landscape dynamics and provides a frame of reference for evaluating modern patterns, processes, and their interactions. In the western United States, understanding historical fire regimes is particularly important given ongoing climatic changes and their effects on fire regimes (Miller and Safford 2012, Westerling 2016, Abatzoglou et al. 2017). Yet, all methods used to reconstruct historical forest conditions have limitations. Confidence in the results generated by any single method increases when multiple studies, using diverse methods, converge on comparable results. Early timber inventories in western ponderosa pine and mixed-conifer forests (Collins et al. 2011, Hagmann et al. 2013, 2014, Collins et al. 2015, Stephens et al. 2015, Hagmann et al. 2017) document forest conditions that are consistent with other records and reconstructions of historical vegetation patterns and fire regimes on landscapes that experienced frequent low- to moderate-severity fires. In a recent assessment of early timber inventories, Baker and Hanson (2017) (hereafter B&H) concluded that these inventories of large forest landscapes in the Central and Southern Sierra Nevada in California and the eastern slopes and foothills of the Cascade Range in Oregon systematically underestimated historical tree density and were biased toward areas of large, merchantable trees. Here, we document serious errors in B&H due to the following: (1) biased estimates of historical tree density from land-survey data; (2) incorrect assumptions about the accuracy of early timber inventories; (3) inappropriate comparisons of studies of vastly different spatial scales, forest types, and diameter limits; (4) unsubstantiated criticism of bias in early timber inventories; and (5) inappropriate cross-referencing and misrepresentation of high-severity fire in historical records.

BIASED ESTIMATES OF HISTORICAL TREE DENSITY FROM LAND-SURVEY DATA

The method used by B&H to estimate historical tree densities (column labeled “General Land Office” [GLO] in B&H Tables 1–3) overestimates known tree densities. In a recent study, Levine

et al. (2017) evaluated the performance of the plotless density estimator (PDE, Williams and Baker [2011]) used by B&H to calculate pre-management era forest composition from witness trees recorded during the GLO survey of public lands. In six forest stands with densities ranging from 159 to 784 trees/ha, the PDE used by B&H produced results that ranged from 1.2 to 3.8 times larger than the true tree density. A fundamental flaw in the method used by B&H, as applied in dry conifer forests, is reliance on crown radius to predict tree spacing. From an analysis of more than 6000 stem mapped trees, Levine et al. (2017) found only weak relationships between crown area and tree spacing.

During revision of this response to B&H, Baker and Williams (2018) published a critique of Levine et al. (2017) addressing purported flaws in the methodology of Levine et al. (2017). These assertions are either irrelevant (e.g., issues with scale or site locations) or invalid (e.g., issues with the designation of neighborhood density; C. R. Levine, J. J. Battles, C. V. Cogbill et al., *unpublished manuscript*). Additionally, Baker and Williams (2018) suggest a correction in estimating tree diameter at stump height (dsh, 30 cm) from measurements of tree diameter at breast height (dbh, 137 cm), based on Baker and Williams' unpublished, private data. By their calculation, this revised dsh-to-dbh ratio would bring estimates of tree density closer to the true density. A forthcoming response to this critique of Levine et al. (2017) reevaluates the importance of the dsh correction of dbh on plotless density estimates. New model runs demonstrate that increasing the dsh-to-dbh ratio by as much as 1.23, as recommended by Baker and Williams (2018), had little effect on reducing the overestimation of density inherent in the PDE they use. Thus, the estimates of historical density B&H compared with early timber inventories overestimate historical densities.

INCORRECT ASSUMPTIONS ABOUT THE ACCURACY OF EARLY TIMBER INVENTORIES

Quality control records from two-chain timber inventories used by Collins et al. (2011, 2015) and Haggmann et al. (2013, 2014, 2017) refute assertions that these early timber inventories were unreliable due to "large underestimation

errors." In the early 1900s, agencies conducting the timber inventories performed "check cruises" on a subset of the area inventoried. We obtained check cruise data from the same archives as the original inventories. At the spatial scales at which these inventories are used, comparable tree densities were recorded in duplicate cruises of the same areas (Table 1). Mean differences of 4–11% between original inventories and check cruises reveal a slight tendency for overestimation of tree density in the original inventories. The interquartile range of differences in tree density measurements between the original inventory and check cruise was –6% to 19%; the range of the middle 80% of values was –29% to 39%. Negative values indicate lower tree densities (or volume) in the original cruise than the check cruise.

To support the contention of inaccuracy of historical timber inventories, B&H (page 4) argued that crews had to work so fast that "...only a few minutes could be spent tallying the tree data" and therefore they did not have time for careful measurements. B&H based their estimate of time spent tallying trees on inventory methods substantially different from those described in the methods sections of Collins et al. (2011), Haggmann et al. (2013, 2014), Collins et al. (2015),

Table 1. Difference between original and check cruises calculated as percentage of the density estimate in the original cruise.

Metric	Collins et al. (2015)	Haggmann et al. (2013, 2014)	
	Stanislaus NF	Klamath	Warm Springs
No. transects	16	274	51
Mean difference, %	5	4	11
Median difference %	–6	3	15
SD %	46	28	32

Notes: Negative values indicate the original cruise was lower than the check cruise; positive values indicate the inverse. Check cruises in the 1911 Stanislaus National Forest inventory dataset (Collins et al. 2011, 2015) measure cruisers' accuracy at estimating distances and tree diameters by comparing timber volumes from the original cruise (in which pacing was used to estimate distance and ocular estimation or Biltmore sticks to estimate diameters) to the check cruise (in which chains were used to measure the length and width of the strips and calipers were used to measure tree diameters). In the 1914–1925 timber inventories of the Klamath Reservation and Confederated Tribes of Warm Springs Reservation in eastern Oregon, check cruises provided a measure of consistency by comparing tree tallies of different cruisers.

Stephens et al. (2015), and Hagmann et al. (2017). The method B&H cited, the Vogel method, was used in the Southwestern Region (USFS Region 3) and entailed subsampling along the transect line. B&H derived their estimate of time available for tallying trees from a description of this method in which the cruiser customarily worked alone and completed 24 transects per day (Marsh 1969). On the one- and two-chain inventories critiqued by B&H, crews of two or three men divided the work of inventorying trees, mapping topography, navigating, and recording site conditions. Travel between transects was minimized as crews worked in consecutive strips. For the records used in Collins et al. (2011, 2015), cruisers completed an average of 8.4 transects per day (median 8, maximum 19). Crews completed a comparable number of transects per day (average 8.7, median 8, maximum 16) in the one-chain inventory records used by Stephens et al. (2015). Crews typically completed 16 transects per day (average 15.9, median 16, maximum 25) in the inventories used by Hagmann et al. (2013, 2014, 2017) based on 2072 transects in one randomly selected township from each reservation. Actual time spent tallying trees per transect is not known; however, given an 8-h day, an average of 8 or 16 transects per day, crews of two to three men, and minimal travel time between transects, we estimate cruisers spent roughly 30–60 min per transect tallying trees. Thus, time available to tally trees in these early timber inventories far exceeds B&H's estimate of a "few minutes" per transect.

INAPPROPRIATE COMPARISONS OF STUDIES

Differences in scale, sampling bias, minimum diameter, and site quality (B&H Tables 1–3; Table 2 in this paper) invalidate B&H's assertion that the timber inventories require correction multipliers for tree density. Early one- and two-chain timber inventories systematically sampled 10–20% of large landscapes (10^3 to 10^5 ha) across broad elevational and topographic gradients. Along these gradients, inherent variation in the growing environment and fire histories inevitably produced broadly varying tree densities. B&H reduced this variability in tree density to a single mean density, which they then compared to other studies without regard for similarity in

site quality. B&H (page 17) advocated a bioclimatic envelope approach to "objectively identify appropriate" areas for comparisons. However, they failed to follow their own advice.

B&H's more detailed analysis of the Greenhorn Mountains timber inventory contains additional errors. B&H incorrectly combined (1) records for trees of unknown size and (2) average values derived from different areas and vegetation classifications in their reassessment of a subset of the 1911 timber inventory of the Greenhorn Mountains (originally summarized by Stephens et al. 2015). Inconsistent documentation of smaller tree sizes in the inventory records analyzed by Stephens et al. (2015) precludes quantitative estimation of density for trees <30.5 cm dbh. Cruisers tallied trees 15–30.5 cm dbh on only 9% of transects. Over 69% of the study area, cruisers provided rough estimates of density for "immature growth" by species; however, diameter limits were not recorded. On 14% of the transects, a qualitative assessment (e.g., "fair" or "good") of immature growth was recorded. Because the diameter range for the immature trees is unknown and the level of detail of these notes varies across the study area, Stephens et al. (2015) used these handwritten notes to assign transects to the relative regeneration classes shown in their Table 3. Thus, these handwritten notes were assessed in Stephens et al. (2015), not omitted as suggested by B&H (page 5).

B&H added the average immature tree density from a subset of transects to the density of trees >30.5 cm derived by Stephens et al. (2015: Table 6) for the entire study area (221 mixed-conifer transects and 157 ponderosa pine transects), incorrectly combining averages for unmatched samples. The southern portion of the Stephens et al. (2015) study area that was reassessed by B&H (Fig. 2) included 199 transects. Using the vegetation classification from Stephens et al. (2015), 137 of these transects were ponderosa pine and 62 were mixed-conifer forest. B&H used a different classification for forest type and reported a sample size of 71 for both the ponderosa pine and mixed-conifer groups (B&H: pages 10–11). Due to both (1) uncertainty in tree diameters and (2) mismatch in average values derived from different areas and vegetation classifications, the tree densities calculated by B&H for the Greenhorn Mountains are meaningless.

Table 2. Errors of fact and omission made by B&H in inappropriate comparisons (B&H: Tables 1 and 2) of mean densities from early timber inventories with other studies of historical tree density.

Studies compared by B&H, and description of errors in comparisons	Nature of errors
Hagmann et al. (2014) and aggregated plot data (Munger (1917)) B&H misrepresent Munger's intentions by stating that "Munger (1917) aimed to characterize ponderosa pine forests in general." In fact, Munger's (1912) purpose for collecting the data presented in Munger (1917) was to estimate future yield. Munger (1912) clearly stated his sampling bias: "The figures for the total stand per acre on these tracts are high and should not be considered as being estimates of the yield over large areas in the locality. They are large. . . partly because the sample acres are <i>taken only in well stocked areas</i> where there are no bare ledges, meadows, or other openings such as are scattered through yellow pine forests and reduce the yield for a large tract."	Unreconciled differences in sampling bias, misrepresentation of data
Hagmann et al. (2014) and tree-ring reconstruction (Merschel et al. [2014]) Merschel et al. (2014) restricted "... the potential sampling area to forested areas (>20% canopy) within putative areas of older forest (>5 large trees/ha)." Additionally, Merschel et al. (2014) noted that they "likely overestimated the historical density of large trees because our historical estimates included trees that may have recruited in response to harvest of large overstory trees."	Unreconciled difference in sampling bias
Hagmann et al. (2014) and tree-ring reconstruction (Morrow (1985)) Morrow (1985) limited his study area (two 1-ha plots) to ponderosa pine forest with densities ≥ 75 trees/ha (tph) >250 yr old. As B&H note, Hagmann et al. (2014) did not compare inventory data with Morrow's data. The comparison had been made previously. Morrow's reconstructed densities are comparable to those recorded on higher density transects in the inventory (Hagmann et al. 2013, Table 6). The comparison was not repeated in Hagmann et al. (2014) because that paper focused on mixed-conifer forests	Unreconciled difference in sampling bias and scale
Collins et al. (2011, 2015) and tree-ring reconstruction (Scholl and Taylor (2010)) Densities from Scholl and Taylor (2010) are misrepresented by B&H. The density estimate of 86.2 tph from the Scholl and Taylor reconstruction is not "from the timber inventory area" as claimed by B&H; it is for the entire reconstruction area. The density estimate of 86.2 tph used a 15.2 cm minimum diameter cutoff (Scholl and Taylor 2010, Table 3), while the density estimate of 141.5 tph used a 10 cm minimum diameter cutoff (Scholl and Taylor 2010, Table 1). Thus, for comparisons with Collins et al. (2011) and Collins et al. (2015), which used a 15.2 cm minimum diameter, 86.2 tph is the appropriate reference number	Unreconciled difference in minimum diameter limit
Collins et al. (2015) identified distinct forest type groups based on vegetation structure and composition. B&H erroneously compare average density (48.1 tph) from all of the forest type groups, which spanned considerable gradients in elevation and productivity, with reconstructed density in Scholl and Taylor (2010), which only represents the high-productivity portion of the mixed conifer zone. The most relevant estimate from Collins et al. (2015) for this comparison is the forest type group labeled as "mixed-conifer, large trees" group, which had an average density of 72.3 tph, reasonably close to both the reconstruction estimate of 86.2 tph and the corresponding timber survey estimate from Scholl and Taylor (2010), which <i>overlapped the reconstruction area</i> , of 99.4 tph	Inappropriate comparisons of different site qualities

UNSUBSTANTIATED CRITICISM OF BIAS

We find no evidence in either historical records or in the studies that used these early timber inventories (i.e., Collins et al. 2011, Hagmann et al. 2013, 2014, Collins et al. 2015, Stephens et al. 2015, Hagmann et al. 2017) to support criticisms (B&H: pages 1, 9–10, 13–15) of (1) bias toward areas of large, merchantable trees; (2) failure to include previously burned areas; (3) inclusion of areas logged prior to the inventory; or (4) lack of cross-validation with independent historical sources. The timber inventories in question comprised 10–20% samples of large landscapes (10^3 – 10^5 ha); used systematically located transects; and included areas the cruisers deemed

capable of supporting tree cover, whether trees were present at the time of the inventory or not. Summaries of these early timber inventories show that sampled areas included transects with little to no tree cover in areas capable of supporting forest as well as in previously burned areas (Collins et al. 2011, Hagmann et al. 2013, 2014, Collins et al. 2015, Stephens et al. 2015, Hagmann et al. 2017).

Bias toward areas of large, merchantable trees

On the Klamath Reservation (hereafter Klamath), the inventory extends continuously from lower to upper treeline; on the Warm Springs Reservation (hereafter Warm Springs), the inventory extends continuously from lower treeline to

above the limit of forest types typically associated with frequent-fire (Hagmann et al. 2014). As clearly illustrated in Hagmann et al. (2014) by Fig. 1 (extent of mixed-conifer forest types) and Fig. 5 (transect locations), essentially all of the area classified as dry and moist mixed conifer on the Warm Springs was both inventoried and included in summary statistics. As systematic samples across these extensive forested areas, there is no evidence to support criticism that the inventories were biased toward areas of large, merchantable trees within the sampled area. If B&H meant to suggest that selection of these two reservations in toto represents a bias toward areas of large, merchantable trees, no evidence has been presented to support this assertion.

Similarly, the timber survey datasets analyzed in Collins et al. (2015) and Stephens et al. (2015) are systematic samples that included non-timber areas and show no bias toward areas with more merchantable timber. The dataset from Stanislaus National Forest used by Collins et al. (2015) includes transects in the rugged Tuolumne River Canyon where no merchantable timber was present. Rather than omitting these areas, the surveyors noted “Broken mountain, brushland, no timber” on the associated datasheets. In the survey data from the Greenhorn Mountains used by Stephens et al. (2015), the transects located within quarter-quarter sections at the edge of the surveyed area often ended in chaparral, and in many instances, surveyors noted the distance along the transect at which they hit the timber line (Stephens et al. 2015: Table A1). Since transects extended past timbered areas, the assertion that “younger, denser forests” were present outside of and intentionally omitted from the surveyed area is unfounded.

Vegetation in California is strongly controlled by elevation; on all sides of the surveyed area in the Greenhorn Mountains, the landscape generally decreases in elevation, transitioning into vegetation types not dominated by conifers. B&H note 17 quarter-quarter sections (roughly 275 ha) adjacent to the study area that today are at least partially categorized as conifer under the California Wildlife Habitat Relationships (CWHR) vegetation database (www.dfg.ca.gov/biogeodata/cwhr/). However, use of these CWHR maps to identify small areas of contemporary conifer forest is inappropriate because the models were

developed to predict vegetation types at an extremely coarse spatial scale (1:1,000,000; Collins et al. 2016). Other adjacent lands omitted from the timber survey were private lands, denoted as “patented” on maps drawn by surveyors. As described by Collins et al. (2016), these non-surveyed areas were incorrectly interpreted as evidence of extensive high-severity fire by Hanson and Odion (2016).

Inclusion of burned areas

Hagmann and colleagues made no attempt to exclude burned areas, and, as illustrated in the following examples, reported on the evidence of high-severity fire effects, despite assertions to the contrary made by B&H (pages 13–14). Hagmann et al. (2013): “Stand-replacing fire effects (“no timber, old burn”) were noted on only five BIA timber inventory transects (8 ha) in this area and these were in and adjacent to sites classified [by the Integrated Landscape Assessment Project] as dry and moist Shasta red fir (*Abies magnifica*) habitat types, not ponderosa pine or mixed-conifer sites.” Hagmann et al. (2014): “High-severity fire effects were documented at the upper elevation boundary of moist mixed-conifer habitat adjacent to colder, wetter habitat types.” Hagmann et al. (2017), Appendix B: evidence of fire in three independent historical records (one of which is the early timber inventory) was compared for 39,000 ha.

B&H (pages 13–14) suggested that conclusions about the dominant influence of frequent, low-to moderate-severity fire on ponderosa pine and mixed-conifer forests by Hagmann et al. (2013, 2017) misrepresented historical conditions due to the exclusion of areas burned at high-severity in 1918 fires. However, these conclusions are consistent with Weaver’s (1961) description of the fires (excerpted by B&H), which suggests limited stand-replacing fire effects from extensive (>80,000 ha) fires in 1918: “Little is known of the 1918 fire, except that it covered most of the central portion of the reservation and that in general it did not cause excessive damage, except where it crowned through lodgepole pine stands and in the vicinity of Skellock Draw and Military Crossing. There it crowned in patches of ponderosa pine. Extensive pole stands of this species there date back to the 1918 fire.” A study of the 1918 fires (Hagmann et al., *unpublished manuscript*)

using dendrochronological reconstruction of fire history, aerial imagery, and timber inventory records quantifies the extent of these “extensive” patches of crown fire; confirms conclusions about the dominant fire regime; is consistent with Weaver’s (1961) description; and confirms preliminary results presented in Hagmann (2014).

Inclusion of logged areas

Logging in the time between GLO surveys and early timber inventories does not account for the substantial difference in tree density between the inventories and the GLO-based estimates of tree density used by B&H, despite claims to the contrary (B&H: page 15). Tree densities recorded in other early timber inventories (Collins et al. 2011, Hagmann et al. 2013, Collins et al. 2015, Stephens et al. 2015, Hagmann et al. 2017) are consistent with those recorded in a comparable dataset for the Warm Springs on which industrial logging did not begin until the 1940s (Logan 1983), long after the 1922–1925 timber inventory of the reservation (Hagmann et al. 2014). The first contract for a commercial timber sale on the Warm Springs was entered into in 1923. However, no harvesting occurred until a breach of contract lawsuit was settled in 1940, and the logging units were resold (Logan 1983). A 1925 letter from the superintendent of the Warm Springs to the Commissioner of Indian Affairs makes clear the frustration he felt at the lack of progress in preparations for harvesting due to the resultant lack of improvement in the financial situation of tribal members and in the reduction of the risk of uncontrollable fire (Mortsof 1925). Logging history and erroneous claims that logging altered tree density before these areas were inventoried have been addressed previously (Hagmann et al. 2013, 2014, 2017).

Cross-validation with other sources

In their criticism that early timber inventories lack cross-validation with other independent sources of data, B&H (page 12) ignored abundant published material that demonstrated similarity between timber inventories cross-referenced with early records and reconstructions of historical forest conditions. Stephens et al. (2015) found substantial similarity in forest structure between early timber inventory records from the Sierra Nevada and (1) historical forest

reconstructions from frequent-fire ecosystems elsewhere in California and in the southwest and (2) plot data from Jeffrey pine-dominated, mixed-conifer forests in the Sierra San Pedro Mártir, Mexico, which have not experienced widespread fire exclusion or harvesting (Dunbar-Irwin and Safford 2016, Rivera-Huerta et al. 2016, van Wagendonk et al. 2018). The historical densities B&H (Table 1) compared with Hagmann et al. (2014) all fall within the range of variability recorded in early timber inventories for central and southcentral Oregon (Hagmann et al. 2013, 2014). Most recently, Hagmann et al. (2017) found that the early timber inventory for 39,000 ha in southcentral Oregon is consistent with earlier independent records of historical forest conditions for the same area (1866–1909 GLO, www.blm.gov/or/landrecords/; 1899–1900 United States Geological Service, USGS, Walcott 1900; and 1930 USFS, Harrington 2003) in both dominance by ponderosa pine and widespread distribution of medium and large ponderosa pines. As noted by B&H, Scholl and Taylor (2010) found 1911 timber inventory records comparable to tree-ring reconstructions of historical forest density. B&H suggested that this “one case of better accuracy . . . could just indicate a good day.” However, the more probable explanation for similarity in tree density in this comparison is the high degree of overlap in sampled areas, unlike the comparisons made by B&H (see *Inappropriate comparisons of studies* and Table 2).

INAPPROPRIATE CROSS-REFERENCING AND MISREPRESENTATION OF HIGH-SEVERITY FIRE

B&H misrepresent cross-validation of inferences about historical fire derived from GLO-based estimates of tree density. Methodological errors in sources B&H (page 2) cite as cross-validation have been documented. Specifically, Stevens et al. (2016) documented errors in inferences about historical fire regimes based on modern Forest Inventory and Analysis data, and Collins et al. (2016) documented errors related to inappropriate use of habitat range maps as well as misinterpretation of early timber inventories. Due to space limitations, we describe errors in cross-validation with only two additional sources: 1911 timber inventory data for the Greenhorn Mountains (Stephens et al. 2015) and

earliest available aerial photographs (Hessburg et al. 2007). Note that B&H (page 2) use the definition of high-severity fire proposed by Agee (1993), >70% tree basal area mortality.

B&H erroneously infer high-severity fire solely from descriptions of vegetation conditions in the 1911 inventory records for the Greenhorn Mountains. B&H inferred high-severity fire from surveyors' field notes on shrubs and young trees as well as the timber condition notes reproduced by Stephens et al. (2015). B&H (Appendix S2) most commonly cited the following conditions as evidence of high-severity fire: "widely scattered mature trees with substantial fire damage, and chaparral within the conifer zone, young oak regeneration, and/or immature conifer regeneration in the understory—often with numerous snags and/or downed logs." The assumption that this condition necessarily indicates high-severity fire is incorrect. First, as the preponderance of scientific evidence suggests "widely scattered mature trees with substantial fire damage" are also associated with frequent, surface-fire dominated, low- to moderate-severity fire, which maintained relatively low tree density in most dry ponderosa and Jeffrey pine forests and many areas of mixed-conifer forest (Stine et al. 2014, Hessburg et al. 2016, Safford and Stevens 2017, Spies et al. 2018).

Second, B&H assumed that the presence of shrubs and young oaks or conifers in the understory arose as a consequence of high-severity fire. Yet, an uneven aged, multi-cohort structure with a shrub understory was common in frequent-fire forests of the Sierra Nevada. The patchy nature of surface fire kills only a subset of young trees and maintains canopy gaps that allow sufficient insolation to sustain understory shrubs. Knapp et al. (2013) analyzed data collected in 1929 prior to any logging on three plots in the central Sierra Nevada. These plots had a median fire return interval of 5–9 yr, had no evidence of high-severity fire in the fire record, and had not burned since 1889. Small trees (10–30 cm dbh) were abundant on these plots, making up 66% of the total stem density. A complete survey of shrub cover was also conducted in 1929 for these plots; shrub cover averaged 28.6%. Clearly, the presence of young trees and shrubs does not necessarily indicate high-severity fire.

Third, B&H infer high-severity fire from the presence of numerous snags and downed logs.

However, if high-severity fire had occurred, the number of dead trees noted by cruisers would be expected to be much higher than the number of live trees. This was not the case for any transects surveyed in 1911. Furthermore, when dead timber was noted, the surveyors typically cited insect mortality as the cause and rarely noted fire damage (see condition of timber survey notes, reproduced in Table A1 in Stephens et al. 2015). Consistent with Stephens et al. (2015), B&H included the presence of chaparral, immature stands with no fire damage, and a patch of fire-killed trees as evidence of high-severity fire. However, as noted by Stephens et al. (2015), chaparral patches are common within the conifer zone, particularly in areas with thin soils and high solar radiation and therefore do not always indicate the occurrence of high-severity fire.

B&H erroneously compared percentage of high-severity fire in their studies, which defined high severity as >70% of tree basal area killed, with Hessburg et al. (2007), which defined high severity as mortality of the dominant life form (e.g., grass, shrub, or tree cover). Metrics from these studies are incompatible and any comparison between them invalid. Hessburg et al. (2007) showed that pre-management era fires in dry mixed conifer were strongly surface-fire dominated (>51% overstory canopy percentage); see their Fig. 6. High-severity fires, which affected about 20% of the dry mixed-conifer potential vegetation type (range across three ecoregions, 10–30%, see their Fig. 5), occurred primarily on grass and shrubland cover types, in areas capable of supporting forests (see their Table 1, where <30% tree canopy cover indicated sparse woodlands or minimally forested patches). In areas where the dominant vegetation cover was either grass or shrub, the high-severity fires indicated the flammability of the dominant grass or shrub cover—not that of the sparse tree cover. High-severity fires were also indicated where stand initiation structures were present, but this represented the minority of cases (18% of cases on 18% of sampled area, Hessburg et al. 2007: page 12).

CONCLUSIONS

We refute suggestions that these early timber inventories are biased and require correction

multipliers for tree density. We find no evidence of systematic bias in the density estimates (Table 1) or of “intentional bias toward large merchantable timber and against younger, denser forests with non-merchantable timber or burned areas.” Numerous errors of fact and interpretation limit the usefulness of this B&H contribution to a better understanding of historical forest conditions and the processes that structured them. Furthermore, previous publications have also documented errors in methodology or misrepresentation of the work of others in papers published by Baker and/or Hanson (for details, see Brown et al. 2008, Safford et al. 2008, Spies et al. 2010, Fulé et al. 2014, Safford et al. 2015, Collins et al. 2016, Stevens et al. 2016, Hagmann et al. 2017, Levine et al. 2017, Miller and Safford 2017, O’Connor et al. 2017).

The value of these early timber inventories exceeds the record they provide of historical tree density. Their key value is in the extensive, detail-rich record of landscape conditions that were resilient under the natural variability of fire regimes and the consistency of those conditions with other records and reconstructions of historical forest conditions and fire regimes. Historical records and reconstructions are useful to understanding variability in historical fire frequency, severity, and spatial extent, as well as variability in the forest successional conditions that emerged from historical fire regimes. Further work is needed to assess the appropriate scope of inference of early timber inventories and of other records and reconstructions of historical forest conditions. Ecologically relevant comparisons with these historical timber inventories could be improved by first sampling the inventories to select comparable growing space or sampling biases. Improved understanding of historical fire regimes and successional conditions is inherently useful to informing management and policy to promote forest conditions that will be resilient under the variability of fire regimes throughout the western United States, even as forests adapt to a warming climate.

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