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# Fire Severity in the Sierra Nevada Revisited: Conclusions Robust to Further Analysis

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## Abstract

In our previous article (Odion and Hanson, *Ecosystems* 9:1177–89, 2006), we reported that fire severity in the conifer forests of the Sierra Nevada mountains of California, contrary to prevailing assumptions, did not burn with predominately stand-replacing, high severity fire. The reply by Safford and others (*Ecosystems*, this issue) using a new mapping approach also found this pattern. Their methods identify more high severity fire; however, as we illustrate here, this may be attributed to the different mapping approaches used. We previously also found that condition class based upon fire return interval departure (FRID) was not an effective predictor of fire severity. Safford and others (this issue) concluded that there was a strong correlation between FRID-based condition class and fire severity based upon data from the McNally fire of 2002. The difference between these findings about McNally fire reflects the fact that they combined FRID categories whereas we kept the categories separate. Here, using their fire severity data to evaluate all three fires, we found that severity was not predicted by FRID. Developing a consensus definition of fire severity within the scientific community might help alleviate future contradictions regarding fire effects.

**Key words:** BAER; conifer forests; condition class; FRID; fire severity; mapping methods.

## Introduction

In Odion and Hanson (2006), we tested two prevailing assumptions about fire in the forests of the Sierra Nevada mountains in California: (a) that wildland fires in these forests currently burn ''almost exclusively'' with high severity, stand-replacing fire (Skinner and Chang 1996; USDA 2004); and (b) that condition class based upon the degree of fire return interval departure (FRID) effectively identifies areas that will burn at high severity (USDA 2004). We found that neither assumption was supported based on burned area emergency rehabilitation (BAER) data. We did not take the opportunity to describe the limitations of BAER data, however. We therefore appreciate that Safford and others addressed these limitations in their reply. BAER data limitations are important to consider because the data have been widely used by scientists and land managers to assess both soil effects and forest mortality resulting from fire (Miller and Yool 2002; Parsons and Orlemann 2002; Parsons 2003; Azuma and others 2004; Alexander and others 2006). It is also important to consider the limitations and assumptions of the new mapping approach employed by Safford and others. Although their analysis supports our con-

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clusions by finding that the same forests burned mostly at low and moderate severity, they reported a higher proportion of high and moderate severity. Mapping definitions and assumptions influence the precise proportion of high and moderate severity effects. Therefore, we first address how the definitions and assumptions affect the proportions of fire severity reported in Safford and others. In addition, Safford and others addressed FRID-based condition class, finding it ''strongly correlated'' with fire severity. However, they only applied their approach to the McNally fire, not the other two large fires we analyzed, and they combined FRID categories we kept separate. Thus, our second objective is to present data for all the FRID categories in all three fires to determine whether the metric strongly predicted occurrence of high severity fire.

## Methods

We used U.S. National Park Service-Geological Survey dNBR data (see explanation of dNBR in Safford and others), which are available online for the McNally Fire (but not Storrie and Manter; http://burnseverity.cr.usgs.gov/fire_main.asp), to calculate fire severities and to compare the effects of severity thresholds used by Safford and others with those recommended by Key and Benson (2005). We also analyzed background literature on the methods employed by Safford and others, and presented by Miller and Thode (2007), including the composite burn index (CBI). To evaluate FRID-based condition class for all categories in all three burns of interest, we digitized fire severity maps from Safford and others, in which the high severity threshold was based on canopy mortality levels of 85% for the Manter and Storrie fires, and 90% for the McNally fire. We determined FRID-based condition class and corresponding fire severity in montane and upper montane conifer forests using the methods described in Odion and Hanson (2006).

## Results and Discussion

Fire severity in the McNally fire using dNBR and the thresholds recommended by Key and Benson (2005) was 9, 34, and 56% for high, moderate, and unchanged/low severity, respectively, similar to BAER. Using the thresholds in Miller and Thode (2007), which were used by Safford and others, we found dNBR fire severity proportions of 32, 26, and 42% for high, moderate and unchanged/low severity, respectively, almost identical to the RdNBR severities reported by Safford and others (see Figure 3c). Key and Benson (2005) recommend a dNBR threshold of 660 for identifying high severity fire, and Collins and others (2007), in an analysis of two Sierran fires, used this threshold for identifying high severity fire and describe severities below this as having little or no stand-replacing fire. In contrast, a dNBR threshold value of 367 is described as high severity in Miller and Thode (2007), which falls into the lower moderate severity category recommended by Key and Benson (2005).

The problem in Safford and others of overestimating fire severity by selecting low severity thresholds is compounded by the relationship between canopy mortality and tree mortality. For example, Thode (2005) found that 80% canopy mortality equated to 65% mortality of individual trees in Sierra Nevada fires. This estimate includes subcanopy trees as small as 20 cm dbh (Thode 2005). Subcanopy trees are abundant in Sierran forests. They are much less fire-resistant than the large trees that dominate basal area rather than stem density (Stephens and Finney 2002). Thus, high levels of stem mortality may be measured when understory trees are counted, whereas reduction in basal area may be relatively low. This may be exacerbated by the CBI methods, which count trees as small as 5 m in height, which are often less than 20 cm dbh. In addition, the CBI level used for indexing high severity that was chosen by Miller and Thode (2007), 2.25, represents only 51–69% mortality according to the CBI field data sheet (Key and Benson 2005). Moreover, the CBI averages the values for up to five soil and vegetation strata. Only one stratum contains overstory canopy trees. Thus, tree mortality may be lower than indicated by the CBI score. Further, the CBI rapid assessment allows field crews to count a tree as dead if they believe it may die up to 2 years after surveys (Key and Benson 2005). In addition to the potential for the CBI methods to cause overestimation of high severity fire, Miller and Thode (2007) also found that areas classified as high severity by dNBR and RdNBR actually met the criteria for moderate severity in CBI field plots more often than vice versa. Others have found that Landsat dNBR methods ''severely underestimated'' the ''green vegetation cover'' (Kokaly and others 2007).

We also found that the data of Safford and others do not indicate that FRID-based condition class was ''strongly correlated'' with fire severity (Figure 1). In fact, contrary to assumptions about dramatic increases in fire severity with increasing FRID, when all three fires were considered, burn severity tended to remain about the same or decrease at

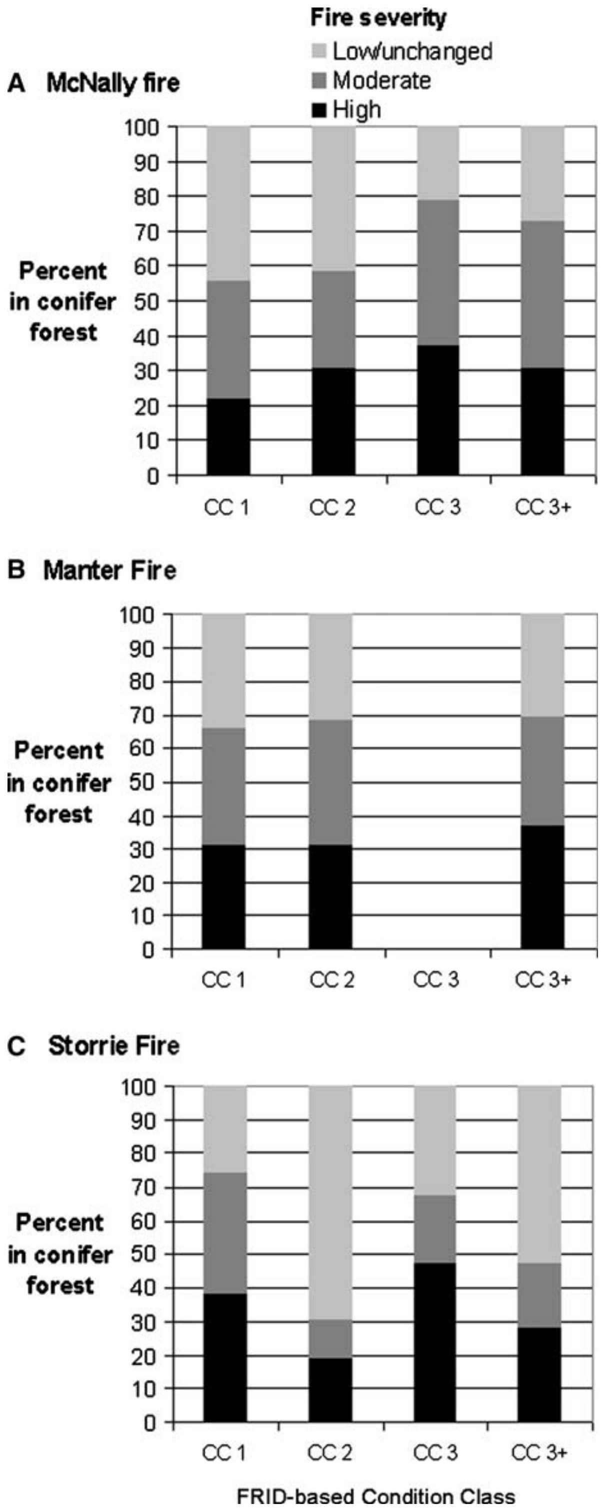


**Figure 1.** Burn severity as a function of FRID-based condition class in the A. McNally, B. Manter, and C. Storrie fires based on the severity data presented in Safford and others (2008) that used 90, 85, and 85% canopy mortality thresholds, respectively, for high severity. Condition class categories 1, 2, 3, and 3+ correspond to low, medium, high, and extreme FRID.

higher FRID levels. The apparent correlation in Safford and others between FRID and fire severity in the McNally fire resulted, in part, from combining the FRID categories that we kept separate in Odion and Hanson (2006), specifically condition classes 3 and 3+. In our current analysis, using the RdNBR severity data of Safford and others, condition class 3+, which predicts the most extreme fire severity, had 31% high severity in the McNally fire (the same as condition class 2), compared to 37% in condition class 3 (Figure 1). In the Storrie fire, there was 28% high severity fire in condition class 3+ areas, which was considerably lower than in condition class 3 areas. In all three fires, condition class 3+ areas had mostly low and moderate severity effects. The prevailing management assumption that, in high condition class categories, fire will burn so exclusively at stand-replacement levels that there is a great risk of ''ecological collapse'' (USDA 2004), is therefore not supported by the data for the McNally, Manter, and Storrie fires, which together represent the majority of the area burned in the Sierra Nevada 2000–2006.

In conclusion, dNBR and the RdNBR system used by Safford and others did not produce different results in conifer forests—rather, the use of different severity thresholds produced the differences. This, along with CBI methods, may lead to inclusion of moderate severity effects in the high severity category. With regard to FRID-based condition class, more study is needed to understand why the longer absence of fire did not effectively predict high fire severity. Finally, in light of the ecological importance of fire-mediated heterogeneity in conifer forests, including patches of high severity (Noss and others 2006), development of a consensus definition of fire severity within the scientific community might help alleviate future confusion regarding fire effects.

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