Southwestern Oregon's Biscuit Fire: An Analysis of Forest Resources, Fire Severity, and Fire Hazard

David L. Azuma and Glenn A. Christensen[1]

Abstract.—This study compares pre-fire field inventory data (collected from 1993 to 1997) in relation to post-fire mapped fire severity classes and the Fire and Fuels Extension of the Forest Vegetation Simulator growth and yield model measures of fire hazard for the portion of the Siskiyou National Forest in the 2002 Biscuit fire perimeter of southwestern Oregon. Post-fire severity classes are related to pre-fire torching indexes, and torching indexes seem to be correlated with the pre-fire volume of stands. Our analysis represents an initial look at fire severity, hazard, and forest attributes.

Fire is one of the most serious disturbances to occur on western landscapes (Agee 1993), and the 2002 fire season was one of the worst in recorded history in Oregon. Total acreage burned exceeded 800,000 acres. The largest fire was the Biscuit fire, which burned for 55 days before being contained. The Biscuit fire perimeter encompassed more than 500,000 acres in Oregon and California, with 460,000 acres in Oregon. Suppression costs in 2002 for southwestern Oregon, including the Apple, Tiller, Timber Rock, and Biscuit fires, were estimated to be more than $200 million, with approximately $150 million spent on the Biscuit fire alone.

The Biscuit fire offers a unique opportunity to study the effects of and recovery from a major wildfire on reserved and nonreserved lands. The reserved area includes the 180,000-acre Kalmiopsis Wilderness Area, which is entirely within the fire boundary. Nonreserved lands are all other areas and are considered potentially available for active forest management such as timber harvest. Forest types range from moist coastal Douglas fir to knobcone pine to a variety of hardwood types.

In the aftermath of the fire, land managers at the Siskiyou National Forest have had to deal with policy debates concerning salvage logging and whether or how to implement reforestation measures. The size of the Biscuit fire has focused public attention on fire risk, forest health impacts, and salvage logging.

The U.S. Department of Agriculture Forest Service's Forest Inventory and Analysis (FIA) program collects and analyzes data that directly contribute information to the debate on post-fire recovery options. Our report describes the Biscuit fire study, presents several inventory results from analyzing the pre-fire data, and explains the data collection that occurred during the 2003 field season. We used the pre-fire information to describe each plot's characteristics, and then related these to post-fire severity estimates derived from the Burn Area Emergency Recovery (BAER) team's severity map. To evaluate how well post-fire severity related to pre-fire measures of fire hazard, we used the Fire and Fuels (FFE) (Reinhardt and Crookston 2003) of the Forest Vegetation Simulator (FVS).

Methods

For the Biscuit fire, we arranged the remeasurement in 2003 of all the Continuous Vegetation Survey (CVS) plots (Max *et al.* 1996) installed by the national forest system in the mid to late 1990s. Along with the standard plot remeasure, we added various post-fire descriptive parameters to help us make inferences about fire severity and its effects on trees and soils. Post-fire tree parameters included percent crown colors (percent of crown that was brown, green, and black), two scorch heights and azimuths, percent stem black, and cause of death. Additional ground variables included percent cover of new litter and depth, previous litter and depth, previous humus and depth, and percent charring levels on previous litter, humus, soil, rock, moss, brown cubical rot, liverworts, and lichens.

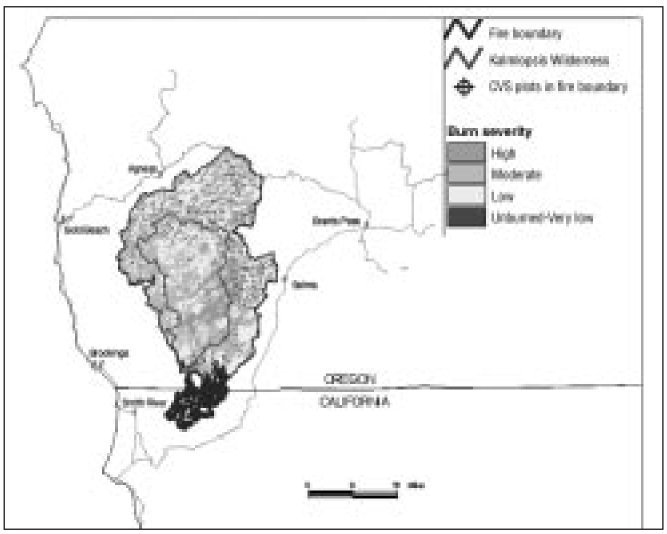
The pre-fire data set consists of a systematic grid of 180 field plots in the fire perimeter (fig. 1). Tree parameters include, but are not limited to diameter at breast height (d.b.h.), height, age, species, compacted crown ratio, and insect and damage

[1] Research Forester and Forester, respectively, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, P.O. Box 3890, Portland, OR 97208-3890; e-mail: dazuma@fs.fed.us.

information. Plot variables include standard site descriptors and coarse woody debris and understory vegetation cover transects. Some variables are used as inputs to the FFE model to estimate fire-related plot attributes such as torching index, crowning index, canopy bulk density, and canopy base height.

We used the BAER team's severity map and compared pre-fire data among four severity classes: very low or unburned, low, moderate, and high (Parsons and Orlemann 2002) (table 1). The map (fig. 1) was based on automated classification of 30-meter pixel Landsat 7 satellite imagery and was field-validated and calibrated using ground crew and helicopter reconnaissance. The minimum mapping size for the severity classes was 50 acres. Using a geographic information system (GIS), the FIA field plot centers were overlaid on the severity map to assign a severity class to each plot.

Figure 1.—*Map of Biscuit fire by BAER burn severity class. Continuous vegetation survey (CVS) inventory plots included in the fire boundary are on a 3.4-mile grid for reserved lands and a 1.7-mile grid for nonreserved lands.*



We used the southcentral Oregon and northeastern California (SORNEC) FVS variant to estimate pre-fire conditions. The SORNEC variant includes the FFE fire model used to calculate canopy base height, torching, and crowning index for each plot. Torching index (TI), representing the wind speed at which fire could be expected to move from surface fuels into crown fuels, is highly influenced by vertical stand structure (ladder fuels). The higher TI values indicate that a higher wind speed is required to move the fire into the crowns, giving these TI values a reduced fire hazard compared with plots that have a lower TI. Crowning index (CI), the wind speed at which a crown fire could be expected to be sustained, is heavily influenced by crown bulk density (Van Wagner 1977). Both TI and CI are used as indexes of potential fire hazard. FFE model defaults are used for pre-fire estimates of all plots. These defaults include these assumptions: 70^{o} Fahrenheit temperature, a 20-foot wind speed of 6 miles per hour, and moisture assumptions that depend on predicted fuel loadings. Fuel loading predictions are estimated from cover type and structural stage. After fuel loading was determined for a particular plot, the plot was assigned one of 13 stylized fuel models dependent on the specific FFE variant. Potential fire estimate calculations were done using Rothermel's 1972 fire behavior prediction system (Reinhardt and Crookston 2003).

Table 1.—*Description of Burn Area Emergency Recovery (BAER) severity classes.*

Collapsed class	BAER burn severity	Description of fire effects
Low/unburned	Very low or unburned	Mosaic of unburned and very low severity ground fire. Consumption of ground cover and vegetation mortality is minimal. Canopy remains vigorous and green. Mortality of trees and shrubs is slight.
	Low	Vegetation is lightly scorched, large trees are mostly not killed, and very small diameter fuels consumed.
High/moderate	Moderate	Much of the litter has been consumed. Fine fuels close to the ground may be all consumed, and trees may exhibit 40- to 80% mortality.
	High	Complete consumption of tree crowns has occurred, few to no leaves or needles remain on trees, and mortality can be assumed to be close to 100%.

Site Description

The Siskiyou is one of the most florally diverse national forests. The complex geology, transverse nature of the Siskiyou Range, and extreme climate conditions combine to provide a variety of niches. The inventory plots contained 14 coniferous and 12 hardwood species. The Forest has 100 different sensitive species and 15 different plant series that can be divided into 92 different plant associations.

Inventory Overview

Within the Biscuit fire perimeter, six major forest types comprised more than 85 percent of the land area. Nonstocked area and forest types with less than 5 percent of the area accounted for the remaining land area. Douglas fir was the most prevalent forest type inside and outside the reserved area, followed by tanoak and western white pine. Generally, few differences existed between the percentage of area by forest type when comparing the reserved and nonreserved areas (table 2).

We estimated pre-fire volume to be 7.02 billion board feet, of which 2.4 billion occurred in the Kalmiopsis Wilderness Area and 4.6 billion on nonreserved lands. The proportion of the total volume by species is constant between the reserved and nonreserved areas and is presented as a combined statistic in table 3. The major species regardless of land status is Douglas fir, with around 70 percent of the volume, followed by sugar pine and tanoak. The average torching index, crowning index, and canopy base height are also presented as a combined statistic for reserved and nonreserved lands by forest type in table 3.

Results

Although the fire area is divided by reserved and nonreserved status, the forest statistics are similar. The percentage of area in the four major softwood types (Douglas fir, sugar pine, western white pine, and Jeffery pine) is the same for the reserved and nonreserved (table 2). The greatest discrepancy appears in the age class distribution, in which the reserved and nonreserved have 53 percent versus 37 percent of the area in the 100–200-year age class. Surprisingly, the nonreserved area has a greater percentage of area in the 200 and older year age class, with 29 percent, versus 15 percent in the reserved (table 4).

The relationship between burn severity and land status is presented in table 5 by area and percentage. The percent of acres burned in the various severity classes are relatively close between the reserved (45 percent) and nonreserved (35 percent) areas in the high and moderate severity classes combined.

The plots that have higher TI tend to be in areas classed as low or very low severity and to have more volume per acre than in areas classed as high severity (table 6). Figure 2 shows a similar relationship between TI wind speed and average plot volume by graphing the average TI by average volume per acre for both the high/moderately burned stands and the low/unburned stands. TI tends to be highest for plots with more volume per acre than those with less volume. Also, as figure 2 shows, the TI tends to be lower for the plots that were most severely burned when compared to those with little or no burn damage.

Table 2.—*Estimated pre-fire area and percent by reserved status by forest type for the Oregon portion of the 2002 Biscuit fire, Siskiyou National Forest.*

Forest type	**Nonreserved area**		**Reserved area**	
	Acres	*Percent*	*Acres*	*Percent*
Douglas fir	132,000	46	72,800	42
Jeffery pine	14,400	5	—	—
Sugar pine	6,100	2	12,600	7
Western white pine	28,000	10	23,900	14
Canyon live oak	15,500	5	10,100	6
Tanoak	43,200	15	33,300	19
Nonstocked	14,800	5	7,500	4
Others	31,500	11	14,400	5
Total	**285,500**	**100**	**174,600**	**100**

Table 3.—*Estimated pre-fire gross board foot volume, torching index, crowning index, and canopy base height by forest type, 2002 Biscuit fire, Siskiyou National Forest.*

Forest type	**Total volume** *Million board feet, Scribner rule*	**Torching index** *Average (m.p.h.)*	**Crowning index** *Average (m.p.h.)*	**Canopy base height** *Average (feet)*
Douglas fir	4,971	7.9	42.2	13.9
Jeffrey pine	113	4.4	105.1	13.4
Sugar pine	804	4.7	71.4	11.5
Western white pine	163	2.3	50.8	6.5
Canyon live oak	18	8.5	104.5	21.9
Tanoak	335	12.0	76.3	25.8
Others	614	5.9	84.5	16.2
All species	7,018	6.9	60.6	14.5

Table 4.—*Estimated pre-fire area and percent of total fire area by reserved status and stand age class for the 2002 Biscuit fire, Siskiyou National Forest.*

Age class	**Nonreserved area**		**Reserved area**	
Years	*Acres*	*Percent*	*Acres*	*Percent*
20–39	7,500	3	0	0
40–59	9,600	3	—	0
60–79	32,600	11	17,000	10
80–99	28,800	10	32,500	19
100–119	25,400	9	23,400	13
120–139	12,500	4	24,500	14
140–159	30,700	11	6,300	4
160–179	18,600	6	31,400	18
180–199	20,800	7	6,300	4
200–299	68,600	24	25,800	15
300 and older	14,000	5	0	0
Nonstocked	14,400	5	0	0
Total[a]	**283,600**	**100**	**174,600**	**100**

[a] One plot was not assigned an age class, accounting for the discrepancy in area totals.

Table 5.—*Estimated pre-fire area, standard error, and percent by reserved status and BAER burn severity class for the 2002 Biscuit fire, Siskiyou National Forest.*

Burn severity	**Nonreserved area**		**Reserved area**	
	Acres	*Percent*	*Acres*	*Percent*
High	38,000	13	33,000	19
Moderate	62,000	22	46,000	26
Low	117,000	41	56,000	32
Very low	68,000	24	39,000	22
Total[a]	**285,000 (4)**	**100**	**175,000 (5)**	**100**

[a] Standard errors for the totals are presented.

Table 6.—*Average volume, large to small tree ratio, down woody material volume, percent understory cover, torching index, crowning index, and canopy base height with standard errors by BAER burn severity class.*

	BAER burn severity			
	High	**Moderate**	**Low**	**Very low**
Volume per acre				
(1,000 board feet, Scribner rule)	10.6	7.8	17.6	24.7
Standard error	2.5	1.7	1.8	2.6
Small tree to large tree ratio[a]				
(number of trees)	94.5	102.6	76.8	30.0
Standard error	24.1	26.3	13.3	4.6
Down woody material > 5 inches in diameter (tons/acre)	4.23	4.46	9.14	5.58
Standard error	1.84	1.27	1.97	1.45
Cover in 1–5-foot height class (%)	43	43	31	23
Standard error	5	3	4	4
Torching index (miles/hour)	4.2	4.2	7.0	10.2
Standard error	1.0	1.2	1.4	1.6
Crowning index (miles/hour)	74.8	66.6	48.3	59.6
Standard error	12.2	7.9	4.2	5.1
Canopy base height (feet)	11.2	9.2	14.2	20.9
Standard error	2.2	1.5	2.1	3.2

[a] Computed as the number of nonsawtimber trees to sawtimber trees.

In a chart of average TI by burn severity and site class (fig. 3), two important trends become apparent. The average torching index tends to decrease (representing an increased hazard) as site class declines, regardless of burn severity, and the most severely burned areas tended to have lower torching indexes than areas burned only slightly or not at all. Because a positive correlation between a stand's potential volume per acre and site quality exists, figures 2 and 3 both show a decrease in torching index with declining site quality or stand volume. The areas in the Biscuit fire that had more standing volume, and which also tended to be on the more productive sites, suffered less fire impact as measured by BAER burn severity.

The relationship between severity class and crowning index is not as strong. The smallest mean crowning indexes were in the low and very low severity classes, but the difference in crowning indexes between low/very low and moderate/high burn severity is small. Perhaps one explanation for this result is that when the fire is in the crowns, it takes about the same wind to move it through the crowns. These data suggest that the plots that burned the most severely are those that had lower torching indexes, as indicated by the FFE estimates. The results listed in table 3 show how TI, CI, and canopy base height differ by the major forest types in the burn area. The average CI for all forest types is high and indicates a lower probability of a fire moving through the crowns than the chance of it moving from a ground fire up into the canopy.

Some interesting differences in torching index were found among forest types. Pine forest types (Jeffery pine, sugar pine, and western white pine) tended to be more susceptible to torching than the other major forest types (fig. 4). We found that the forest types with the highest pre-fire TI (lowest hazard) are the two major hardwood types, canyon live oak and tanoak. The percentage of BAER severity by forest type results support the TI by forest type results. As with TI, the three pine types tended to have the greatest percentage of area in the two highest severity categories, moderate and high (fig. 5). The BAER mapping also showed that the two major hardwood types, canyon live oak and tanoak, had the least percentage of burn in the two most severe classifications.

Discussion

Data from the FIA plots in the Biscuit fire boundary enable exploring how pre-fire plot characteristics relate to post-fire severity estimates based on the BAER map. One of our most important findings is that plots with a higher timber volume and on more productive sites appear to have lower torching hazard; as the trees increase in size, they tend to dominant the stand, excluding the brush component and smaller trees (table 6), thereby reducing the ladder fuels and reducing the incidence of torching. The low and very low severity plots also had the highest canopy base heights, although only the very low severity plot base height was significantly different. The generally higher canopy base heights and lower ladder fuels appear to be related to the lower burn severity. After the ground-based measurements of severity are analyzed, this hypothesis can be further explored.

Figure 2.—*Average torching index by BAER burn severity and stand volume class. As average volume 1,000 board feet/acre increases, torching index tends to also increase suggesting the possibility of decreased torching potential in the stand.*

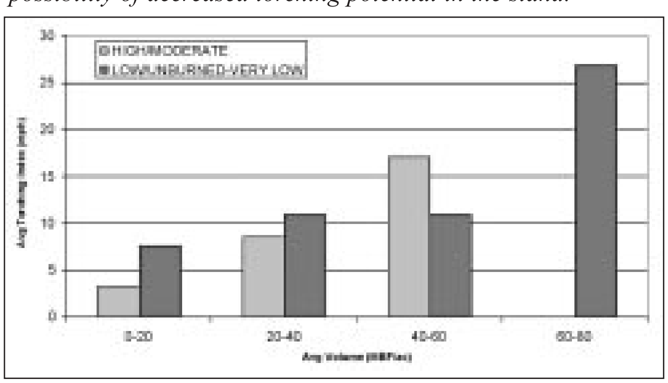
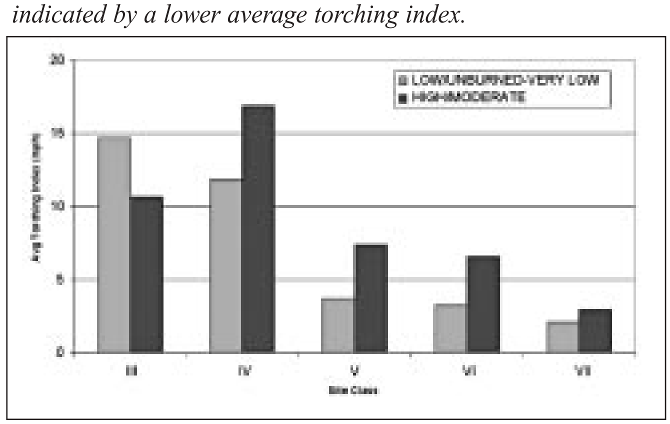


Figure 3.—*Average torching index by BAER burn severity by average torching index and site class. High productivity is indicated by lower site classes. High probability of torching is indicated by a lower average torching index.*



For our analysis, we found that using FFE to provide pre-fire estimates of torching index appears to be a useful approach to identify areas that may be severely impacted by wildfire. Further analysis of post-fire ground-based measurements of severity, however, will provide better estimates of the nature and strength of this relationship. Crowning index did not provide the same utility in terms of predicting burn severity, but this may be due to factors specific to this fire, such as forest types and stand structures, topography, and the intensity of this fire.

The differences in average torching index by forest type is another important finding from this analysis. A clear difference exists between the torching index prevalent for the three major pine types (Jeffery, western white, and sugar) and the high TI prevalent for the two major hardwood types (fig. 4). Like our findings of the relationship between torching index and burn severity, these results can only be confirmed definitively with ground-based measurements.

Our study is the first analysis relating various fire modeling parameters to burn severity and pre-fire stand characteristics. The reserved and nonreserved areas are similar in terms of area burned by BAER severity class but differ by stand age class distribution. The nonreserved acres had the largest area in the oldest age class. We found that the plots classed as low or very-low burn severity tended to have more volume per acre than the more severely burned plots. These plots also tended to have less cover in the stand's small tree and brush component and have a higher average canopy base height. Using the FFE model to estimate specific fire related parameters such as torching and crowning index, we found BAER burn severity was closely related to torching index, but much less related to crowning index. Torching index was less for those plots that were the most severely burned, suggesting that this may be a useful variable to assess current fire hazard. Torching index also tended to drop when volumes per acre and site quality decline. Azuma *et al.* (in press) provides a more in-depth explanation of various resource parameters and their relationship to burn severity. All the results presented here use the BAER team's remote sensing based method of classifying fire severity and may not reflect fine-scale, on the ground differences in severity. Future research will include analyzing post-fire measures of severity on stands and the relationships between pre-fire stand characters (topographic and vegetative) and fire weather.

Figure 4.—*Average torching index by forest type. Pine forest types tend to have a lower torching index wind speed, indicating a potentially greater probability of torching occurring in these types.*

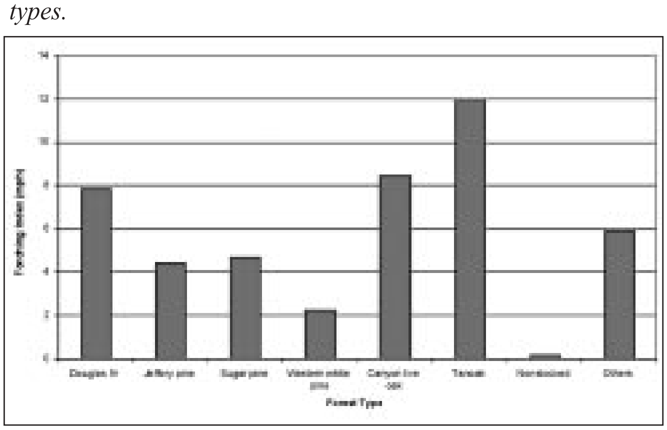
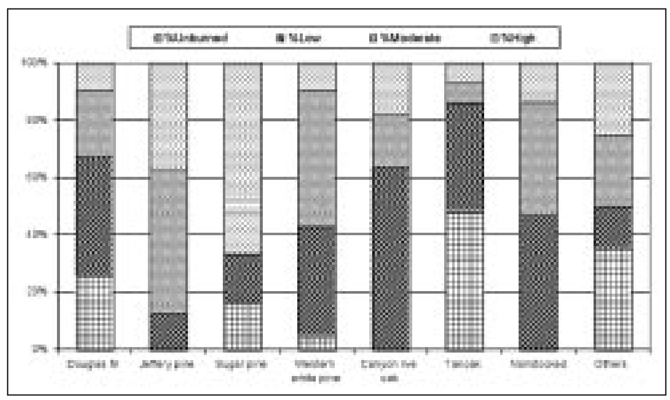


Figure 5.—*Percentage of major forest types by BAER severity class. Pine forest types tended to exhibit an increased occurrence of the more severe BAER classes, moderate and high.*



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