Fire Ecology Vol. 4, No. 1, 2008
doi: 10.4996/fireecology.0401074

RESEARCH ARTICLE

MEASURING THE RATE OF SPREAD OF CHAPARRAL PRESCRIBED FIRES IN NORTHERN CALIFORNIA

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ABSTRACT

Prescribed fire is a common method used to produce desired ecological effects in chaparral by mimicking the natural role of fire. Since prescribed fires are usually conducted in moderate fuel and weather conditions, models that accurately predict fire behavior and effects under these scenarios are important for management. In this study, explosive audio devices and steel stakes were used to record the location of the flaming front during seven prescribed fires in mature, chamise (*Adenostoma fasciculatum*) dominated chaparral in northern California. Intervals between detonations measured the time required for five fires to transverse a fixed distance and were used to estimate the rate of spread (ROS) during headfire burning conditions. In two other fires, a stopwatch was used to measure the time required to travel successive 5 m distances and ROS was calculated. Burns were completed during moderate weather conditions: average temperature 17 °C, average relative humidity 42 %, and wind light and variable, generally from the west ranging from 0 km h^{-1} to 8 km h^{-1}. Average percent moisture was 92.1 % for chamise live one-hour fuels, and 8.8 % for chamise dead one-hour fuels. Live fuel height averaged 1.2 m. Overall average ROS was 0.36 m s^{-1} (range 0.22 m s^{-1} to 0.56 m s^{-1}) for areas where the flaming front advanced upslope. Measurements of ROS were indeterminable for many of the points along the line transects due to lack of visibility from smoke and from fire not traversing the terrain as predicted. For comparison, BehavePlus fire modeling was performed using five different shrub fuel models (NFFL 4, SH5, SH7, SCAL15, SCAL17); all models underestimated ROS and flame length with NFFL model 4 producing values most similar to that recorded during the prescribed fires. Users of the recently developed fuel models may benefit from field studies to verify model adequacy and fire behavior predictions.

Keywords: chamise, fire behavior, flame length, fuel model, fuel moisture, live fuel, shrub cover

Citation: Stephens, S.L., D.R. Weise, D.L. Fry, R.J. Keiffer, J. Dawson, E. Koo, J. Potts, and P.J. Pagni. 2008. Measuring the rate of spread of chaparral prescribed fires in northern California. Fire Ecology 4(1): 74-86. doi: 10.4996/fireecology.0401074

INTRODUCTION

The physical characterization of wildland fuels is important for a variety of uses. The rate at which energy is released determines, in part, the size of flames, the height of the plume above the fire, the rate at which the perimeter of the fire increases, the amount of energy that is absorbed by physical and biological resources in the vicinity of the fire, and the ability of fire management activities to manage fire to accomplish desired objectives. The use of prescribed fire to accomplish resource management objectives has global scope with interest increasing in the last several decades (Pyne *et al.* 1996, Fernandes and Botelho 2003, Anderson *et al.* 2005).

Chaparral is a Spanish word used to describe a vegetation complex found primarily in California, extending south into Mexico and east into Arizona (Keeley 2000). The species composition of this vegetation varies throughout its range. Common woody species include chamise (*Adenostoma fasciculatum*), ceanothus (*Ceanothus* spp.), manzanita (*Arctostaphylos* spp.), and shrub oaks (*Quercus* spp.). Thin bands of riparian vegetation are often interspersed in chaparral along permanent and seasonal watercourses and they provide important wildlife habitat; chaparral is an important bird habitat and species composition is affected by post-fire age gradients of prescribed fires (England 1995; J. Potts, University of California, Berkeley, unpublished data). In southern California, several threatened, endangered, and sensitive plants and animals live in or rely on chaparral, riparian zones, and sage scrub complexes (Stephenson and Calcarone 1999).

In California, chaparral occupies approximately 4 million ha, 10 % of the state's area (Fried *et al.* 2004). Five of California's 10 largest wildfires have occurred in this vegetation type from 1923 to 2005 (Stephens and Sugihara 2006), and prescribed fire is frequently used to manage chaparral. Having accurate information on rates of spread and fireline intensity are important factors when planning prescribed fires. For example, in conducting prescribed fires to manage exotic weed species, if the fire moves too quickly it may not produce the desired ecological effect because of insufficient consumption of the duff layer, surface seeds, and seed heads.

A variety of techniques to manage chaparral have been developed over the past 50 years including grazing, herbicide use, mechanical methods, and prescribed burning (e.g. Green 1981, Conrad *et al.* 1986, Biswell 1989). Prescribed burning is also used to produce desired ecological effects in chaparral by mimicking the natural role of fire. Applying prescribed fire requires a plan that identifies the desired resource outcomes, the fire behavior necessary to achieve the outcomes, the weather and fuel conditions necessary to achieve desired fire behavior, the control forces necessary to conduct the burning, and a risk analysis. The Rothermel (1972) fire model in its various forms is typically the basis for fire behavior calculations used to develop prescribed fire plans in the United States.

The limitations of the Rothermel model for fire spread prediction in live fuels such as chaparral have been described (Lindenmuth and Davis 1973, Cohen and Bradshaw 1986) even though the model has been used with some success (Stevenson *et al.* 1974, Albini and Anderson 1982, Dimitrakopoulos and Dritsa 2003). Live fuels differ from dead fuels chemically and physically, and recent work with chaparral fuels has shown the importance of convection to successful fire spread under marginal conditions (Zhou *et al.* 2005, 2007). Ignition tests of individual chaparral leaves resulted in a wide range in ignition temperatures when a heating rate typical of wildland fires was used (Fletcher *et al.* 2007), and little to no dependence of time to ignition and ignition temperature on leaf thickness and leaf moisture mass was observed. A physical fire spread model initially developed by Pagni and Peterson (1973) was tested with limited success in chaparral prescribed fires and has been recently modified and compared with laboratory rate of spread experiments by Koo *et al.* (2005).

Several fuel models have been developed to represent chaparral for use with the Rothermel fire behavior model. The Northern Forest Fire Laboratory (now the Missoula Fire Sciences Laboratory) fuel model 4 (one of the original 13 fire behavior fuel models – Albini 1976) was primarily developed for chaparral fire behavior prediction during the severe period of the fire season (Anderson 1982). More recently, Scott and Burgan (2005) have developed 40 additional fuel models, two of which may improve accuracy of fire behavior predictions outside the severe period of the fire season, such as prescribed fire applications. Several custom fuel models have also been developed for southern California chaparral (Cohen 1986, Weise 1997) and the Fuel Characteristic Classification System contains descriptions of several chaparral fuel beds (Riccardi *et al.* 2007).

Although there are new research results available describing various aspects of fire behavior in chaparral (e.g., Weise *et al.* 2005, Sun *et al.* 2006), they have not been incorporated into operational fire spread models at this time. Comparison of predicted spread rates from the current tools available to fire managers with observed fire spread rates in operational-scale prescribed burns is therefore useful. Procedures to adjust predicted spread rates to observed spread rates exist (Rothermel and Rinehard 1983, Fujioka 2002); however, the information on actual spread rates in chaparral during prescribed fires is very limited. This research project utilized field-scale fire behavior measurements (ROS and flame length) made as part of a larger group of studies examining fire spread in living shrub fuels (Weise *et al.* 2004) and compared these estimates to predictions calculated from the available shrub fuel models under the same conditions. Information from this study could be used by fire managers to inform plans on the use of prescribed fire in chaparral.

METHODS

Study Location and Prescribed Fire Characteristics

The chaparral prescribed fires were conducted at the University of California Hopland Research and Extension Center (HREC) and at the adjacent US Bureau of Land Management South Cow Mountain Recreation Area (COW) in Mendocino County, California, USA. Two fires were conducted at HREC in late spring of 1995 and five (four at HREC, one at COW) in the fall and winter of 2006-2007. Burns were conducted in mature chaparral on predominately west-facing slopes (Figure 1). The most common shrub species was chamise. Less common shrub species

Figure 1. Prescribed fire in mature chamise-dominated chaparral in northern California. Field estimations of fire rate of spread are complicated by subtle changes in wind, topography, species composition, and canopy cover. Photo by Steve Quarles.

found in the plots include buckbrush (*Ceanothus cuneatus*), Eastwood manzanita (*Arctostaphylos glandulosa)*, and leather oak (*Quercus durata*).

On June 1, 1995, two prescribed fires occurred at HREC (0.25 ha, HREC1; 1 ha, HREC2). One 0.5 ha plot was burned at COW by helitorch on December 1, 2005. At HREC, three plots (1 ha, HREC3; 0.5 ha, HREC4; 0.5 ha, HREC5) were burned on February 4, 2006, and one plot (8 ha, HREC6) was burned on December 2, 2006. Drip torches were used to ignite all prescribed fires with the exception of the one prescribed fire at COW.

Vegetation and Fire Behavior Measurements

In the 1995 burn plots, one transect of steel stakes was installed with 5 m separating each stake. Transects were placed perpendicular to the slope contour in the two burn plots in an effort to ocularly record rate of spread (ROS) during headfire burning conditions using a stopwatch to time intervals between stakes. In the 2006 plots, one to four line transects of varying lengths were installed in each burn plot before burning. At 5 m to 10 m intervals along each transect, explosive audio devices

(Piccolo Pete[1] fireworks or shotgun shell primers) were attached to a branch in the live crown and as the fire passed each interval, detonations were recorded with audio and video tape recorders. Time between successive detonations was used as a measure of ROS[2].

Transect starting points were placed midslope such that the entire transect was in view of observers to confirm detonations or the time when the headfire reached the next steel stake (for 1995 fires). At each interval in the 2006 fires, slope, aspect, maximum live shrub height, and percent cover of all shrub species in a 5 m radius circular plot were measured. In the 1995 fires, the maximum live shrub height and percent cover of all shrub species were measured along the line-transect created by the steel stakes.

Prior to each burn, soil and fuel samples were collected to estimate percent moisture content. Samples were immediately stored in metal 10 cm diameter soil sampling cans and dried in the laboratory for 24 h at 95 ºC. Sample weight before and after drying was measured using an electronic scale with a precision of ±0.01 g. Percent moisture content was calculated on a dry weight basis. Soil was collected at two depths: 0 cm to 3 cm, and 3 cm to 6 cm below the surface. Live and dead 1 h time lag fuels were collected for shrubs with overstory cover greater than 10 %.

Prescribed fires were ignited by hand crews using drip torches (one helitorch ignition) in a headfire configuration (Martin and Dell 1978) to produce relatively uniform fire behavior. Flame lengths were estimated ocularly during the fire and these estimates were reviewed by watching a video taken of the prescribed fires.

Fire Behavior Modeling

Behave Plus (Anderson *et al*. 2005) was used to model fire behavior of the chaparral prescribed fires. In addition to NFFL model 4, SH5 and SH7 shrub fuel models (Scott and Burgan 2005) and chaparral models developed for southern California (SCAL15 and SCAL17; Weise 1997) were used in simulations to determine which would more closely match field results.

Input variables included surface fuel model, fuel moistures, slope, and wind speed. All of these variables were measured in the field with the exception of complete data for 10 h and 100 h dead fuel moisture. Measurements indicated that 10 h fuel moisture was approximately 1 % greater than 1 h fuel moisture, and 100 h was 2 % greater. Assuming that 10 h fuel moisture was 0.5 % greater than 1 h and 100 h moisture was 1 % higher resulted in only a 1 % difference in ROS estimates and almost no change in flame length estimates. To compare with field measurements, model prediction variables were calculated for the average, maximum, and minimum wind speeds recorded during the prescribed fires.

RESULTS

Vegetation and Weather

Most of the transects were installed in nearly pure chamise but a few shrubs of other associated species were found in some plots (Table 1). The height of the chaparral was similar between plots.

For most of the plots, weather conditions were ideal for prescribed burning. Weather for the COW burn plot was influenced by an approaching storm, which resulted in cloudy skies and high relative humidity compared to burning conditions at the other plots (Table 2).

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[1] Trade names are provided for informational purposes only and do not constitute endorsement by the US Department of Agriculture.

[2] A video demonstration of ROS measurements using audio explosive devices in a chaparral prescribed fire is available at http://www.cnr.berkeley.edu/stephens-lab/links.htm.

Table 1. Average (standard error) site and vegetation characteristics for chaparral prescribed fire plots in northern California.

					Cover (%)				
Site	**Date**	**Aspect**	**Slope (%)**	**Max. live fuel ht (m)**	**ADFA**	**CECU**	**ARGL**	**QUDU**	**Bare ground**
HREC1	June 1995	W	43	1.1 (0.1)	84.3 (4.25)	-	1.3 (1.3)	-	14.4 (3.21)
HREC 2	June 1996	SW	28	1.2 (0.1)	68.0 (10.5)	12.0 (8.9)	-	11.0 (10.1)	9 (2.2)
COW	November 2005	SW	21 (6.3)	1.6 (0.2)	100	-	-	-	-
HREC3	February 2006	NW	28 (1.2)	1.2 (0.2)	100	-	-	-	-
HREC4	February 2006	NW	26 (1.4)	1.4 (0.1)	100	-	-	-	-
HREC5	February 2006	W	23 (0.7)	1.3 (0.6)	100	-	-	-	-
HREC6	December 2006	SW	26 (5.4)	1.7 (0.3)	84.8 (17.7)	12.1 (9.1)	17.9 (16.3)	-	-

Note: ADFA, *Adenostoma fasciculatum;* CECU, *Ceanothus cuneatus;* ARGL, *Arctostaphylos glandulosa;* QUDU, *Quercus durata.*

Table 2. Weather observations during chaparral prescribed fires at U.C. Hopland Research and Extension Center and BLM Cow Mountain, northern California.

Site	**Date**	**Time**	**Sky**	**Temp. (˚C)**	**Relative humidity (%)**	**Average direction & wind speed (km h^{-1})**
HREC1	June 1995	1100	Cloudy	21	61	S2
HREC2	June 1995	1200	Cloudy	26	49	SW5-7
COW	November 2005	1400	Cloudy	17.5	53	SW2-8
HREC3	February 2006	1200	Clear	20	34	NNW2-8
HREC4	February 2006	1400	Clear	18.3	36	NW2-4
HREC5	February 2006	1445	Clear	15.5	30	NW2-3
HREC6	December 2006	1300	Clear	18.3	34	SW0-4

Soil and Fuel Moisture

Live fuel moisture contents for the late-spring 1995 prescribed fires (over 130 %) were much higher than those for the 2006 burns. Percent moisture content of the soils and dead fuels reflect the relatively dry conditions under which most burning was conducted. For the December 2006 burns at HREC, 10 h fuel moisture was reported to be 9 % (R.J. Keiffer, University of California, Berkeley, unpublished data). Table 3 summarizes soil and fuel conditions prior to each burn.

Fire Behavior Observations

As expected, plots burned under varying weather conditions that influenced ROS; Table 4

Table 3. Average (standard error of the mean) percent soil and fuel moisture characteristics (dry weight basis) collected prior to burning in northern California chaparral prescribed fire plots at the Hopland (HREC) and Cow Mountain (COW) sites.

	June 1995		November 2005	February 2006			December 2006
	HREC1	**HREC2**	**COW**	**HREC3**	**HREC4**	**HREC5**	**HREC6**
Soil 0-3 cm	-	-	11.6 (0.2)	7.8 (5.5)	13.0 (7.0)	21.3 (3.5)	19.7 (3.9)
Soil 3-6 cm	-	-	10.9 (1.5)	11.57 (2.9)	11.6 (4.8)	19.6 (4.2)	18.1 (2.6)
1 h Live-ADFA	134.4 (10.5)	146.3 (3.8)	57.5 (1.8)	90.7 (11.0)	71.2 (3.1)	80.4 (1.6)	64.4 (3.4)
1 h Dead-ADFA	8.4 (0.2)	8.0 (0.3)	8.9 (0.5)	8.7 (0.3)	7.8 (0.5)	8.8 (0.3)	11.1 (0.2)
1 h Live-CECU	-	139. 6 (16.8)	-	97.1 (14.7)	105.5 (8.9)	95.0 (18.2)	79.9 (4.2)
1 h Dead-CECU	-	-	-	10.1 (0.6)	10.3 (2.3)	8.2 (1.5)	11.7 (2.6)
1 h Live-ARGL	159.1 (16.3)	-	-	-	-	-	86.2 (-)
1 h Dead-ARGL	-	-	-	-	-	-	9.4 (-)
1 h Live-QUDU	-	129.3 (7.5)	-	-	-	-	-

Note: ADFA, *Adenostoma fasciculatum;* CECU, *Ceanothus cuneatus;* ARGL, *Arctostaphylos glandulosa;* QUDU, *Quercus durata.*

Table 4. Average fire behavior (ROS; rate of spread) in chaparral prescribed fires in northern California. Ranges are in parentheses.

Site	Date	ROS (m s^{-1})	Flame length (m)	Comments
HREC1	June 1995	0.32 (0.22-0.42)	7-12	4 intervals obscured by smoke; N = 3
HREC2	June 1995	0.38 (0.3-0.42)	7-18	5 intervals obscured by smoke; N = 2
COW	November 2005	0.56 (0.35-0.7)*	5-20	*ROS influenced by ring ignition and helicopter-induced wind; N = 3
HREC3	February 2006	0.31, 0.23	7.5-12	Direct view obstructed, first point unburned; N = 2
HREC4	February 2006	-	7.5-12	ROS indeterminable, flaming front flanked transect
HREC5	February 2006	0.42 (0.19-0.68)	9-12	Wind blowing across slope influencing ROS; N = 6
HREC6	December 2006	0.22 (0.13-0.39)	9-15	First transect successful, other transects burned by flanking fire; N = 9

summarizes fire behavior observations. Overall average ROS was 0.36 m s^{-1} (range 0.22 m s^{-1} to 0.56 m s^{-1}) for areas where the flaming front advanced upslope. Flame lengths were higher in the HREC2 plot relative to HREC1 because of higher air temperature and lower humidity during burning. Cloud cover was also lower during the HREC2 fire (60 % versus 100 % for HREC1), which could increase fuel temperature and increase flame lengths through increased burning rates and larger flame depths.

Overcast skies and high relative humidity during the COW burn prohibited attempts to ignite with drip torches; therefore, a helitorch was used to apply fire to the entire perimeter of the plot. As a result, the fire moved unpredictably through most of the transect, obviating any upslope ROS measurements. Despite this burning pattern, ROS measurements for this plot were the highest compared to ROS measurements from all other plots, probably because of a ring-fire ignition pattern that was used to ignite the entire unit at once.

For HREC3, view was obscured by a bench in the slope contour, but the flaming front appeared to progress upslope through the transect. A flanking fire burned through HREC4 and therefore ROS was not recorded. Both transects in HREC5 were burned by headfire conditions. However, fire behavior was influenced by wind blowing across the slope and may have increased ROS. For HREC6, the first transect was successful at recording upslope ROS; all other transects within this plot were burned by flanking fire.

Fire Behavior Modeling

NFFL model 4 consistently produced the highest fire behavior predictions and the largest changes in response to varying wind speeds (Figure 2). With the exception of HREC3,

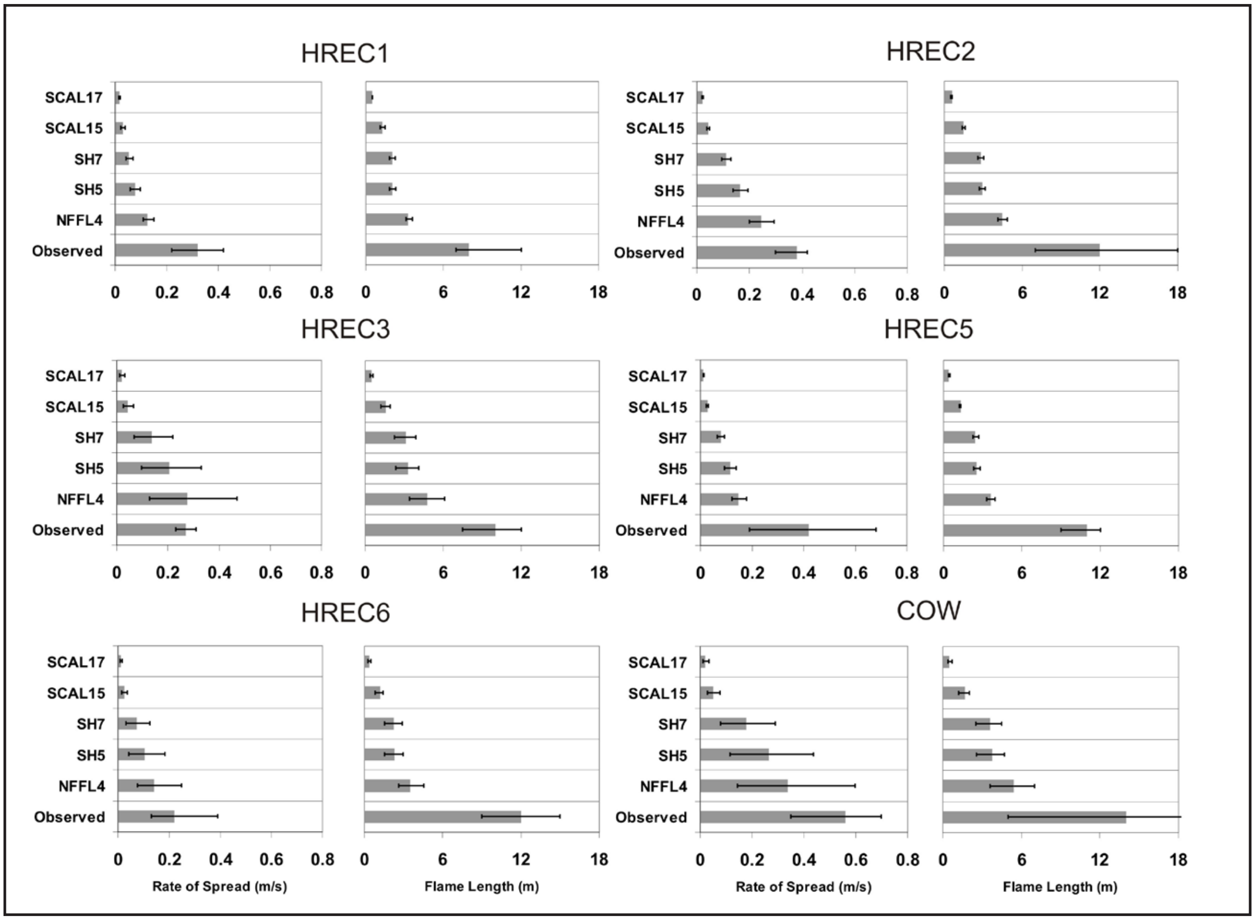

Figure 2. Average northern California chaparral prescribed fire observations (observed; rate of spreads, and flame lengths) and predicted model outputs. Lines represent the range in values for maximum and minimum wind speeds recorded during the prescribed fires. See Tables 1-4 for observation comments and parameters used to obtain model outputs. NFFL 4 from Andrews (1982); SH5 and SH7 from Scott and Burgon (2005); SCAL15 and SCAL17 from Weise (1997).

ROS and flame length predictions ranged from 26 % to 85 % of field measurements for the range of wind speeds recorded during the prescribed fires. NFFL model 4 and SH5 over-predicted ROS at the maximum wind speed for the HREC3 fire. SH5 and SH7 produced ROS estimates that were approximately 50 % to 75 % of that produced by NFFL model 4. SCAL15 and SCAL17 produced the lowest ROS estimates, averaging 12 % to 25 % of those produced by NFFL model 4. Flame length estimates from the different fuel models produced a similar pattern with NFFL model 4, producing the largest estimates, ranging from 27 % to 73 % of field measurements for the range of wind speeds recorded during the prescribed fires (Figure 2).

DISCUSSION

By manipulating prescription variables to produce desired fire intensities (Raybould and Roberts 1981), prescribed burning can be used to increase edge within chaparral for wildlife habitat and to increase biodiversity by creating openings for regeneration (Stephenson and Calcarone 1999). Low intensity prescribed burns in chaparral can be used to reduce fire hazard to riparian habitats; however, resultant hillslope erosion and dry ravel may impact riparian zones (Dougherty and Riggan 1981, Barro *et al* 1989). In contrast, high intensity wildfires often cause extensive changes to chaparral landscapes, which then gradually recover following various successional pathways (Keeley 2000). The ability to more accurately model fire behavior in chaparral can assist in developing prescriptions to meet ecological and management objectives.

Above ground chaparral structure was significantly changed by our prescribed fires as is common in most prescribed fires in this vegetation type. Before the fire, 87 % to 100 % of the seven burn plots were covered by shrubs (Table 1). The relatively dry conditions under which these burns were conducted is reflected in the soil and dead fuel moisture contents, yet the seasonal differences are also reflected in the live fuel moisture contents (Table 2). Despite these variable conditions, after the fire, no live branches were found in the plots or transects, indicating uniform fire coverage. Shrub skeletons did exist in the plots after the fires but were composed of materials with larger diameters.

Implementation of the methods used in this study is relatively easy and can be completed on the day of the burn. Conversely, it is extremely difficult to predict with certainty where the fire will spread and, therefore, precisely where to place the explosive devices or steel stakes. For more than half of the transects installed, the flaming front did not traverse the transects as predicted even though ignitions were specifically applied to produce headfires. While the explosive devices aided in recording ROS when the direct view of the transect was obstructed, tall vegetation or smoke can interfere with observations. Furthermore, the variability in heat required to detonate the explosive devices is unknown and this may add to the variability in ROS estimations. The limitations with these methods are similar to those reviewed in Simard *et al*. (1982); however, the triangle method, recording the time required for a fire to traverse an equilateral triangle (Simard *et al*. 1982, Moore *et al*. 1995), solves the problem of having to predict the precise direction of the flaming front.

When a fire burned through a transect as predicted, the methods used in this study appear to estimate ROS without bias. An inevitable difficulty is accounting for factors such as wind that affect fire behavior in experimental fires (Gould *et al*. 2007) (Figure 1). During some of these prescribed fires, we observed flaming fronts advancing periodically through the vegetation in narrow strips. These leading strips usually occurred at focal points along the ignition line where fire was applied directly to the shrub canopy. Installing transects at predetermined focal points may increase the likelihood of collecting accurate one-dimensional ROS measurements.

Using Behave Plus (Andrews *et al*. 2005), fire behavior model results for the five different surface fuel models (NFFL 4, SH5, SH7, SCAL15, SCAL17) were quite diverse. NFFL fuel model 4 produced results that were the most similar to those recorded from the field even though this model was intended for severe fire weather conditions. Incorporating the range in wind speeds recorded during the prescribed fires into the models, the range of ROS predictions overlapped the averages observed in four of the six prescribed fires (Figure 2). This demonstrates the sensitivity of the live shrub fuel models to varying wind speeds (Weise *et al.* 2005) and the importance of accurately recording wind in the field (Gould *et al*. 2007).

Fuel models SH5 and SH7 produced fire behavior outputs that were 8 % to 70 % of what was observed in the field. This was a bit surprising because these fuel models were developed to more closely simulate prescribed fire conditions when weather tends to be more moderate. Custom fuel models developed for southern California chamise-dominated chaparral produced the lowest ROS estimates, approximately 10 % of what was observed in the field, and do not seem appropriate for northern California chaparral in our study sites.

Flame length estimates from BehavePlus using the five surface models were much lower than what was observed in the field. Comparisons of field measurements and model predictions should be interpreted with caution because observed flame lengths are likely to be overestimated. Flames are inherently unstable and it is difficult to make estimates of their lengths in chaparral fires without reference points. Yet it should be noted that modeled flame lengths were approximately 50 % of observed estimates using NFFL 4 and were much lower in the other fuel models. The HREC5 fire had relatively large ROS and flame lengths when compared to all model outputs (Figure 2). As with most burns, variable wind direction and speed (Table 1 and 2) coupled with ignition patterns may influence fire behavior by preheating fuels, which confounds estimates. Higher wind speeds could have resulted in the larger ROS and flame length estimates for this prescribed fire.

Prescribed fire is one method that can produce desired ecological effects in chaparral by mimicking the natural role of fire. Fire managers utilize available tools such as fuel models to aid in the development of management plans. Because prescribed fires are usually conducted in moderate fuel and weather conditions, models that accurately predict fire behavior and effects under these scenarios are therefore important for management. Experimental fires that measure fire behavior both in the field and in the laboratory are needed to test models and provide information that can be incorporated into future models to improve accuracy.

Current fuel models designed to estimate fire behavior of a flaming front are difficult to verify with field measurements. Uncontrollable factors that exist during experimental fire in the field such as variable wind patterns (Gould *et al*. 2007), topography, and vegetation structure inevitably confound field observations. Measurements of fire behavior (ROS and flame length) from chaparral prescribed fires in northern California were much higher than predictions using the current fuel models. Discrepancies in estimates are due to both the difficulties in estimating fire behavior and inadequacy of the models to predict the dynamic nature of fire in live fuels. Information from this study could be used by fire managers to inform plans on the use of prescribed fire in chaparral.

ACKNOWLEDGEMENTS

The senior author thanks Bob Lane for introducing him to the UC Hopland Research and Extension Center and for being part of the 1995 prescribed fires. We thank the dedication and support of Mark Tolbert and the CalFire engine, ground, and helicopter crews. Funding for this research was supplied by the US Joint Fire Sciences Program and US National Fire Plan. We thank Steve Quarles, all summer technicians and staff at the BLM Ukiah Field Office, and Hopland Research and Extension Center for their assistance. This manuscript was prepared, in part, by a U.S. Government employee on official time and is therefore in the public domain and not subject to copyright laws.

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