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Validation of an Index System for Estimating Fireline Production With Handtools¹

by

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Abstract

Production of hand-constructed fireline was simulated in 32 forest cover types and three slash fuel types in the boreal forest of northern Alberta. A total of 47 double trials were conducted in these 35 fuel types. The first trial simulated an initial attack situation, and the second a sustained attack situation. The results were used to test the validity of the fireline production index developed by Murphy and Quintilio (1978). Correlation coefficients between predicted and measured fireline production rates were 0.93 for initial attack simulations and 0.95 for sustained attack simulations. However, the predicted rates were consistently lower than observed rates, largely because of the methodologies used in classifying resistance categories, and the "over-achieving" syndrome common to participants in behavioral studies. We conclude the index is useful in providing consistent and desirably conservative estimates of handline production rates. These estimates could be adapted for operational application in other regions if they are verified for local conditions. Predictions will be further strengthened if based on data collected from actual fires rather than simulation tests.

Résumé

La construction de coupe-feux établis manuellement a été simulé dans 32 types de peuplements et parmi trois types de combustibles de la forêt boréale du nord de l'Alberta. Un total de 47 essais jumelés ont été réalisés sur ces 35 types de combustible. Le premier essai simulait une situation d'attaque initiale, tandis que le deuxième représentait une situation d'attaque soutenue. Les résultats ont été utilisés pour évaluer la validité de l'index de construction de coupe-feux élaboré par Murphy et Quintilio (1978). Les coefficients de corrélation des taux de construction prévus et mesurés des coupe-feux ont été de 0.93 pour les simulations d'attaque initiale et de 0.95 pour les simulations d'attaque soutenue. Toutefois, les taux prévus étaient constamment inférieurs à ceux observés, principalement par suite des méthodologies utilisées dans la classification des catégories de résistance, et du syndrome de "performance" notée chez les participants d'études de comportement. Nous concluons que l'index est utile pour prévoir des estimés constants et relativement conservateurs des taux de construction manuelle des coupe-feux. Ces estimés pourraient être adaptés à des situations opérationnelles dans d'autres régions advenant qu'ils soient vérifiés sous les conditions prévalentes sur place. Les prédictions seront renforcées à la condition qu'elles soient basées sur les données recueillies lors de feux réels plutôt que sur des simulations.

Introduction

Accurate estimates of fireline production rates have long been recognized as an important tool in forest fire suppression. Early studies of fireline production concentrated on developing faster fireline construction techniques (McReynolds 1936, Anon. 1940, Hulett 1940). Almost as soon as researchers began to measure fireline production rates, they began developing models that used these rates to determine the size of suppression force needed to contain a given fire (Hanson 1941, Hanson and Abell, 1941). Recent models have become more complex, estimating time required to contain a fire, fire size at containment, and probability of containment as well as suppression force requirements (Quintilio and

Anderson 1976, Bratten 1978, Mees 1985, Smith 1986). Smith (1986) showed that estimates of final fire size were significantly affected by the accuracy of fireline production estimates. Lower than expected rates of fireline production have a greater effect on estimates of final fire size than do higher than expected rates (Smith 1986). Therefore, fireline production rates should be conservative or less than those to be expected under worst case conditions.

Unfortunately, most published studies of fireline production have been conducted in fuel types common in the southern United States, typically described by vegetative species. These descriptions are not applicable to boreal forest conditions where species and the fuel complex are different. Murphy and Quintilio (1978) measured production rates for hand-constructed fireline in boreal forest stands, first developing a more generic and widely applicable index system based on a number of resistance-to-control factors. These factors were: tree density by height class, brush cover (%) by height class, number of downed roundwood logs

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> 10 cm in diameter encountered along randomly located 30-m transects, trenching depth, excess roots and rockiness. These descriptions accurately predicted fireline production rates ($r^2 = 0.98$, $p = 0.01$).

Recent papers (Lindquist 1970, Ramberg 1974, Haven *et al.* 1982) have criticized the accuracy and value of previously published fireline production rates developed for the United States. Therefore, the primary objective of this study was to validate the accuracy of the fireline production index system as developed by Murphy and Quintilio (1978) for use in sustained attack situations in boreal forest stands. The approach used by Murphy and Quintilio (1978) is unique compared with other methods. A second objective was to determine whether these same index values (Murphy and Quintilio 1978) could be used to predict fireline construction rates for initial attack situations.

Study Area and Methods

This study was conducted in the boreal forest of northern Alberta, Canada. The boreal forest, as described by Rowe (1972), covers that portion of Alberta north of 54°N latitude. Common coniferous tree species in the area include: lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* [Moench] Voss), and black spruce (*Picea mariana* [Mill.] B.S.P.). Aspen (*Populus tremuloides* Michx.) is the most common hardwood species. The heights, densities, and tree species for the forest cover types sampled are summarized in Table 1.

Hand-constructed fireline production was simulated under the direction of an independent supervisor who followed the methods described in Murphy and Quintilio (1978). Proposed firelines were systematically located in 47 fuel types representative of 32 tree cover types (Table 1). Four of the trials were located in logging slash representative of three different fuel types. Two simulation trials were conducted in each fuel type. None of the authors was present for the trials to avoid influencing construction rates. Before each trial, the resistance-to-control factors for tree height and density, brush height and density, amount of deadfall and slash, depth

to mineral soil, and stoniness were assessed. These data were used to calculate a fireline production rate index using the tables developed by Murphy and Quintilio (1978). Firelines were constructed by experienced Alberta Forest Service fire-fighting crews of various sizes using the sequential method of construction.

For the first trial, the crew was instructed to work at a pace that could be maintained for a maximum of one hour, replicating an initial attack mode. Production was measured over a 20-minute period after a steady state of work output was reached. For the second trial, the crew was instructed to work at a rate that could be maintained for an eight-hour shift, simulating a sustained production rate. The measured rate for the sustained attack simulation was reduced by 25% to account for 15-minute rest breaks normally taken each hour.

Observed fireline production rates were compared to index rates using a paired t-test. The student's t-test was used to compare data collected during this study to data reported by Murphy and Quintilio (1978). All statistical analyses were performed using the Statistical Package for the Social Science (SPSSx) (SPSS Inc. 1983).

Results

Observed rates of fireline production were significantly greater than the corresponding rate predicted from the resistance/production tables in Murphy and Quintilio (1978) ($p < 0.01$) for both the sustained attack simulations and the initial attack simulations (Table 2). This was also the case for the sustained attack simulations conducted by Murphy and Quintilio (1978) ($0.01 < p < 0.05$; Table 2). Compared with the index-based predictions, the rates for the sustained attack simulations were 19% higher. The initial attack mode yielded rates that were twice those for sustained production.

The mean ratio of observed fireline production rate to index rate for the sustained attack simulations in the present study did not differ significantly from the mean ratio for the sustained attack simulations conducted by Murphy and Quintilio (1978) ($p > 0.05$; Table 2).

The coefficient of correlation between observed fireline production rates and index rates ranged from 0.93 to 0.99 for the three sets of simulation that were analyzed (Table 2) and all three coefficients were highly significant ($p < 0.001$).

Discussion

The data from simulation trials conducted for the present study as well as those conducted by Murphy and Quintilio (1978) show that the index developed by Murphy and Quintilio consistently and proportionately underestimates fireline production rates. There are several possible explanations for the differences between predicted index rates and observed rates of fireline production. Murphy and Quintilio (1978) suggested resistance-to-control values may have been conservatively estimated in borderline conditions due to "smoothing of curves and averaging". This resulted in lowering index rates, which in turn would over-predict the size of the suppression force required to control a fire, thus assuring a safety margin in operational situations. It has also been suggested that fireline production rates observed during simulations or training exercises are often higher than those observed on actual fires (Lindquist 1970, Haven *et al.* 1982). The 19%

Table 1. Number of double-trial fireline construction simulations in forested fuel types by tree species^a, tree height, and percent crown closure^b

Percent crown closure	Tree height (m)			
	6-12	13-18	19-24	25-30
6-30	1 PI	2 PI	2 PI	
	1 Sb	3 PJ	1 PJSb	
31-50		1 A		
		1 Sb		
	1 PI	1 PI	1 PI	1 PI
	2 A	1 PJ	1 PJ	2 Sw
	1 Sb	2 A	1 Sw	
51-70			2 SwA	
			1 SwPJ	
	1 PI	1 PI	1 PJ	
	1 Sb	1 A	1 Sb	
		2 Sw		
71-100		1 SbPI		
		2 PJ	1 PI	
		2 A		

^aPI = lodgepole pine, PJ = jack pine, A = deciduous (primarily aspen), Sw = white spruce, Sb = black spruce. ^bDouble trials were also conducted in slash fuel types: PJ (n = 1), PJSb (n = 1), Sw (n = 2).

Table 2. Observed fireline production rates of the present study compared with index fireline production rates from Murphy and Quintilio (1978).

Data Source	n	Mean index rate (m/45-min h/man)	Mean observed rate ^a (m/45-min h/man)	Mean ratio of observed rate to index rate	Correlation coefficient (Observed rate vs index rate)
Murphy and Quintilio (1978) Sustained attack simulation	38	10.1 (1.76) ^b	11.1* (2.12)	1.09 (0.03)	0.99
Murphy and Quintilio (1978) Operational data	14	11.2 (2.04)	14.9 (4.06)	1.15 (0.11)	0.93
Present study Sustained attack simulation	47	12.8 (1.49)	15.0** (1.93)	1.19 (0.50)	0.95
Present study Initial attack simulation	47	12.8 (1.49)	27.1*** ^c (3.32)	2.16 (0.10)	0.93

^a*Indicates significant difference between observed rates and index rates at the 5% level;

^b**Indicates significant difference between observed rates and index rates at the 1% level.

^c^bStandard error of the mean given in parentheses.

^cMeasured rate for initial attack simulation is given as m/60-min h/man.

difference between observed rates and index rates was not considered significant for operational data collected by Murphy and Quintilio (1978) ($p > 0.05$; Table 2). These operational data consisted of 14 observations of production during initial attack on uncontrolled fires, training and line building on a large fire (Murphy and Quintilio 1978).

The technician who supervised the simulations during the current study observed competition among crews and felt the production rates measured during the sustained attack stimulations could not have been maintained over an eight-hour shift (Ponto 1986). It is understandable that crews may have difficulty in estimating a pace that could be maintained over a long period of time. Murphy and Quintilio (1978) also found that actual initial attack rates were often twice the index rates and concluded crew motivation during the initial attack phase was responsible for these discrepancies.

Several fireline production studies in the United States have recognized the effects of fatigue, and have adjusted production rates accordingly (Lindquist 1970, Haven *et al.* 1982, Schmidt and Rinehart 1982). Observed fireline production rates for the initial attack simulation were expected to be much higher than the predicted index rates because the index was developed to predict sustained production rates. The fact that the ratio of observed rates to index rates for the present study did not differ significantly from the ratio for the 1978 study further suggests that the index has not become obsolete due to increases in fireline production. More importantly, the rates predicted do not over-estimate actual production, hence the chances of a fire escaping control are minimized.

In spite of differences between index rates and observed rates for both initial and sustained attack situations, the high correlation coefficients suggest the index proposed is very precise and simply needs minor adjustment to produce accurate estimates for operational applications. If greater precision is required then a factor can be determined to convert the index rates, which were developed for sustained attack, to an accurate estimate of initial attack rates. We believe any adjustment factor for converting index rates to initial attack rates probably should be based on data from actual fires rather than simulations because such factors as motivational incentives, training, leadership and work habits of local suppression forces will affect production rates. Also,

these factors in addition to actual shift rates will enable fire managers to estimate more accurately local sustainable production rates when index values are calculated using the Murphy and Quintilio (1978) method.

The value of this study lies in our approach to predicting actual fireline production rates for crews with handtools. We have demonstrated that easily measured fuel factors can provide the basis for precise predictions of fireline production rates. Although tested in boreal forest stands, the approach verified in this study may also prove to be useful in non-boreal stands. We advise managers to verify the rates presented, but based on the strength of our results it would appear that intensive sampling is not required.

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