VALIDATION AND REFINEMENT OF A PLANT INDICATOR MODEL FOR GRAND FIR MORTALITY BY THE FIR ENGRAVER[1]

RONALD L. MAHONEY, JAMES A. MOORE, AND JOHN A. SCHENK[2]

ABSTRACT

A previously developed plant indicator model that estimates grand fir mortality by the fir engraver was tested in 7 grand fir stands. The observed and predicted mortality levels were similiar in 5 of the test stands for trees killed during a 3-year period. A better statistical fit was achieved by refining the model and its parameters based on a combined set of data from the original and test stands.

Additional Key Words: *Abies grandis, Scolytus ventralis*, understory plants, linear regression, indicator plants.

Recent research on the associated environmental factors and prediction of mortality in grand fir, *Abies grandis* (Dougl.) Lindl., caused by the fir engraver, *Scolytus ventralis* (LeConte), has provided a preliminary model (Schenk *et al.* 1977) that was subsequently validated and refined (Moore *et al.* 1978). The model relates stand composition and average competitive stress to the occurrence and level of grand fir mortality by the fir engraver. Concurrent with this investigation, other research was conducted to identify sites associated with the development of grand fir stands susceptible or resistant to the fir engraver. A preliminary plant indicator model was formulated which accounted for a substantial amount of the variation in fir engraver-caused grand fir mortality (Schenk *et al.* 1976). The predictor variable used in the model is plant group interaction (PGI), a ratio of the occurrence of two groups of plant species associated with high or low grand fir mortality, respectively. A test of that model is reported here.

The data required to compute PGI were acquired during late summer, 1978, according to the method specified by Schenk *et al.* (1976). Seven independent test stands were sampled by a randomly located systematic grid of ten 1/300th acre (0.012 ha) circular plots. On each plot the presence of the specified plant groups was recorded, and the stand frequency of each group was calculated. An estimate of grand fir mortality by the fir engraver was obtained from the results of a previous study (Moore *et al.* 1978), which included these stands. The test stands ranged in area from about 15 to 30 acres (6 to 12 ha), occupied relatively uniform sites in terms of topography and prior disturbance, and had not sustained logging or fire within the past 15 years. Current stand conditions represented a range of overstory density and species composition.

The number of trees killed per acre for each test stand was predicted by the equation developed by Schenk et al. (1976):

$$Y = 2.291 + 0.111e^{X} \quad [1]$$

where: Y = number of grand fir trees killed per acre by the fir engraver during a 3-year period (KTA)
X = plant group interaction (PGI).

Equation [1] produced an r^2 of .92, and a standard error of the estimate of 1.55 trees/acre, and was significant at $\alpha = .05$.

Observed mortality and the predictions derived from equation [1] showed poor agreement (Table 1). These results exemplify some of the hazards of statistical models derived from a small sample and limited range of data, regardless of statistical fit, and of extrapolative predictions outside the range of the original data set. However, a 95 percent confidence interval about each predicted value contained the observed mortality value for 5 of the 7 test stands.

Stand number 3 sustained considerably higher observed mortality than predicted by equation [1]. Equation [1] was derived from stands where root rot pockets involved less than 15 percent of the total stand area. About 40 percent of the total area of stand number 3 consisted of root rot pockets which contained the bulk of grand fir mortality by the fir engraver. Consequently, the presence of root-rot infected grand fir will predispose those trees to attack by the fir engraver (Partridge and Miller 1972) and cause mortality in excess of that indicated by equation [1] when the infected area in the stand exceeds 15% limit included in the original data set.

Stand number 5 had a PGI value of 9.0909, which is numerically larger than the highest PGI value (4.7619) used in equation [1]. However, when the exponential transformation indicated in equation [1] is applied, these values become 8874.1692 and 116.9684. This drastic increase in relative numerical value is reflected in the excessively high predicted value of 987 grand fir trees killed per acre (Table 1). Conse-

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[2]Research Associate, Assistant Professor, and Professor, respectively, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho.

TABLE 1. Observed and predicted levels of grand fir mortality by the fir engraver in northern Idaho.

Stand No.	PGI	ePGI	Stems per Acre Observed	Stems per Acre Predicted
1	0.732	2.079	1.0	2.5
2	0.396	1.486	4.1	2.5
3	0.297	1.346	11.3	2.5
4	0.297	1.346	0.0	2.5
5	9.091	8875.057	17.0	987.0
6	0.000	1.000	2.0	2.3
7	0.099	1.104	4.2	2.4

quently, the mathematical expression that best fits the developmental data set (exponential transformation) is obviously unreliable for extrapolative predictions. However, it is notable that equation [1] performed very well within the range of development data, excluding the influence of excessive root rot. Furthermore, the form of the relationship between PGI and grand fir mortality by the fir engraver remains similar for all of the test stands. We omitted stand number 3 because of excessive root rot from a combined data set that includes the 9 original stands and 6 of the 7 test stands.

The parameters in equation [1] were reestimated from the combined data set using least squares regression. The equation for the combined data set is:

$$Y = 3.8420 + 0.0015e^{X} \qquad [2]$$

where: Y and X are as defined in equation [1].

Equation [2] produced an r^2 of 0.43 and a standard error of the estimate of 4.14 trees/acre, and was significant at $\alpha = .05$. These statistics indicate a poorer statistical fit than equation [1]. Thus, other transformations of the independent variable were tested to better describe the functional relationship. Although a curve form that includes an upper and lower asymptote is a biologically reasonable formulation, the observed data do not include mortality levels approaching the upper asymptote because the fir engraver does not kill 100 percent of the grand fir trees in actuality. Thus, the "best" statistical fit for the range of these data was achieved with an untransformed linear regression dependent on PGI. The equation is:

$$Y = 1.7861 + 1.9097X \qquad [3]$$

where: Y and X are as defined in equation [1]. Equation [3] produced an r^2 of .86 and a standard error of the estimate of 2.08 trees/acre, and was significant at $\alpha = .05$ (Table 2, Figure 1).

Equation [3] performed very well for the combined data set, with high statistical correlation and a low standard error of the estimate. This mathematical expression is also biologically reasonable because a high value for PGI indicates a site less conducive to the maintenance of favorable moisture conditions and vigor of grand fir. The upper and lower limits of PGI values are 100 and 0, respectively. Equation [3] would predict respective mortality levels of 190

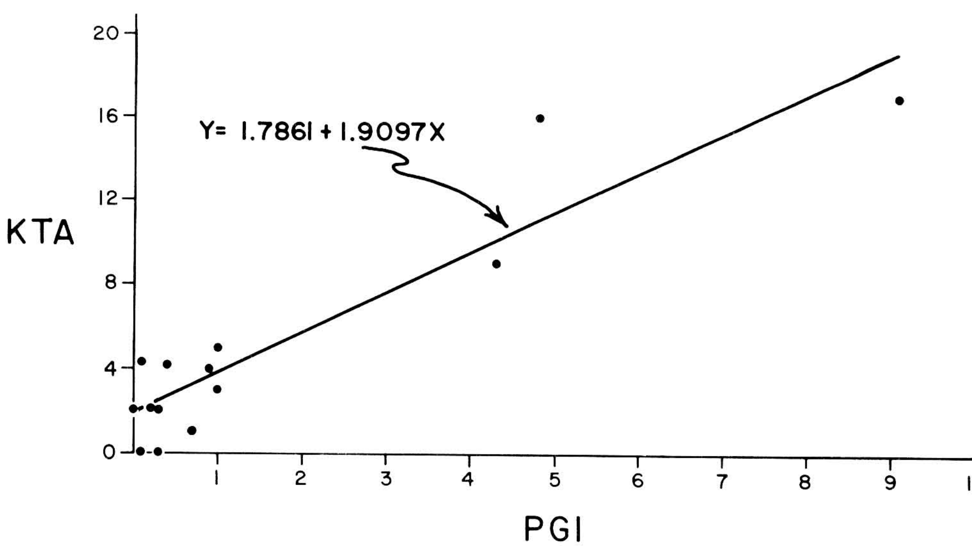

Figure 1. The relationship of plant group interaction (PGI) and grand fir trees killed per acre by the fir engraver (KTA) for 15 stands in northern Idaho, 1978.

TABLE 2. Observed and predicted levels of grand fir mortality by the fir engraver in 15 northern Idaho stands.

	Stems per Acre	
PGI	Observed	Predicted
0.000	2.0	1.8
0.099	0.0	2.0
0.099	4.2	2.0
0.198	2.0	2.2
0.198	2.0	2.2
0.297	0.0	2.4
0.297	2.0	2.4
0.396	4.1	2.5
0.732	1.0	3.2
0.879	4.0	3.5
0.986	5.0	3.7
0.988	3.0	3.7
4.286	9.0	10.0
4.762	16.0	11.0
9.091	17.0	19.0

and 1.8 trees per acre. Thus, equation [3] gives reasonable predictions using the natural extremes of PGI.

Because the sites were undisturbed for at least 15 years and also had a mature overstory, the understory plant community approached climax in all of the sampled stands. Consequently, the differences in plant communities are assumed to reflect site differences rather than levels of secondary succession due to varying disturbance. Thus, the procedures to determine PGI (Schenk *et al.* 1976) should be applied to mature grand fir stands with no apparent ground-level disturbance within at least 15 years. This will help to ensure that the data collected correspond to those conditions sampled in the current study. The process of testing the predictions against an independent data set provides more confidence that equation [3] can produce information useful for forest management planning regarding the relative susceptibility of northern Idaho sites to grand fir mortality by the fir engraver.

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