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A Simple Model for Predicting Annual Numbers of Southern Pine Beetle Infestations in East Texas

James C. Kroll and Hershel C. Reeves

ABSTRACT. Eleven climatic variables, recorded during the period 1966–76, were used to develop a multiple linear regression model for predicting potential number of southern pine beetle (SPB) infestations for east Texas. Four climatic variables were significantly ($P < 0.05$) related to numbers of SPB infestations. These were (1) mean temperature for February of current year, (2) total rainfall for previous summer, (3) total rainfall for previous fall, and (4) total rainfall for previous spring. The regression analysis accounted for 90.7 percent of the variation in yearly numbers of SPB infestations.

The southern pine beetle (*Dendroctonus frontalis* Zimm.) is the single most destructive agent of southern pine forests. Existing control efforts, although often effective on individual infestations, have seemed to be unsuccessful in reducing general population levels from one year to the next (Coster 1977). In an effort to reduce the severity and cost of damage by this insect, a southwider research and applications program (Southern Pine Beetle Research and Applications Program or SPBRAP) was initiated. Application of control measures by land managers will depend heavily upon their ability to anticipate timber losses due to pine beetle activity. Hence, a simple model to predict annual numbers of SPB infestations would be of considerable value.

Several researchers have attempted to delineate environmental factors which directly or indirectly affect southern pine beetle (SPB) populations and activity. Limiting climatic factors examined include moisture availability, moisture abundance, and temperature (Coster 1977). King (1972) compared epidemic and endemic years in order to assess importance of rainfall to SPB activity. Epidemic years were characterized as having (1) low summer rainfall in Georgia, (2) high winter rainfall in Texas, and (3) high spring rainfall and low early summer rainfall in North and South Carolina. In Delaware, Maryland, and Virginia, SPB outbreaks have been associated with prolonged periods of low rainfall (Hansen *et al.* 1973). Kalkstein (1974) noted that, in Texas and

Louisiana, SPB activity was directly related to increased moisture and late winter potential evapotranspiration. In a later study, Kalkstein (1976) developed a regression model designed to predict SPB activity, the most important variable to the regression being evapotranspiration three months prior to the evaluated beetle activity. Sixty-four percent of the variability in SPB activity (measured as increased or decreased number of spots about a mean) was explained by the regression model. Kalkstein's regression model relies heavily on current year's data and makes use of evapotranspiration which may not be readily available to the forest manager.

It is apparent that a reliable method of SPB activity over a broad geographic area has not been developed to date. Development of such a method has been limited because: (1) extent of SPB activity is difficult to determine using current technology, (2) number of SPB infestations detected may or may not be an indicator of current activity or population levels, and (3) contradictory environmental conditions have been associated with beetle activity in different geographical areas. Infested locations, large enough to be detected by air, may be actively expanding in size. These areas may also have declining populations or even be inactive at the time of surveillance.

TABLE 1. Climatic data for forested east Texas.¹

Location	Temperature Means °F			Precipitation (in.) Annual
	Jan	July or Aug	Annual	
Greenville (north)	44	84	64	43
Houston (south)	54	83	69	46
Kirbyville (east)	52	82	67	54
Palestine (west)	49	83	67	41
Mean	<u>48</u>	<u>83</u>	<u>67</u>	<u>46</u>
Nacogdoches (central)	48	82	66	48

¹ Temperature rounded to nearest whole degree; precipitation rounded to nearest inch.

There is a need for a simple technique to predict potential timber losses and manpower needs resulting from beetle activity. We present here a regression model which hopefully allows the forest manager to make such predictions in east Texas prior to peak beetle activity.

DATA COLLECTION

Climatically, east Texas is the western part of the humid subtropical climate characteristic of the southern United States. Nacogdoches is centrally located in the forested east Texas area, and is representative of climatic conditions in the commercial pine forests of Texas (Table 1).

Analysis of weather data indicates close temperature correlation for rather large areas if topographic conditions are similar (Watt 1968). However, rainfall differences for a specific geographic area can be large during short time intervals. Generally, rainfall data will smooth out over time in a given climatic zone. Short term differences do indicate significance of rainfall study on a local scale (Oliver 1973). How much, if any, influence local variation in rainfall has on SPB populations must still be determined.

For the present study, daily weather data collected at the Stephen F. Austin State University School of Forestry Weather Station since 1966 were used to obtain monthly, seasonal, and annual precipitation and temperatures.

Numbers of infestations for each year during the period 1966–76 (Figure 1) were obtained from the Texas Forest Service (Forest Pest Control Section) at Lufkin. Prior to 1974, infestations (=spots) were usually censused from aircraft by counting all infestations containing five or more infested trees; however, beginning in 1974 only infestations containing 10 or more active trees (red tops or faders) were counted.

STATISTICAL PROCEDURES

Stepwise multiple regression analysis was performed using a total of 11 independent variables.

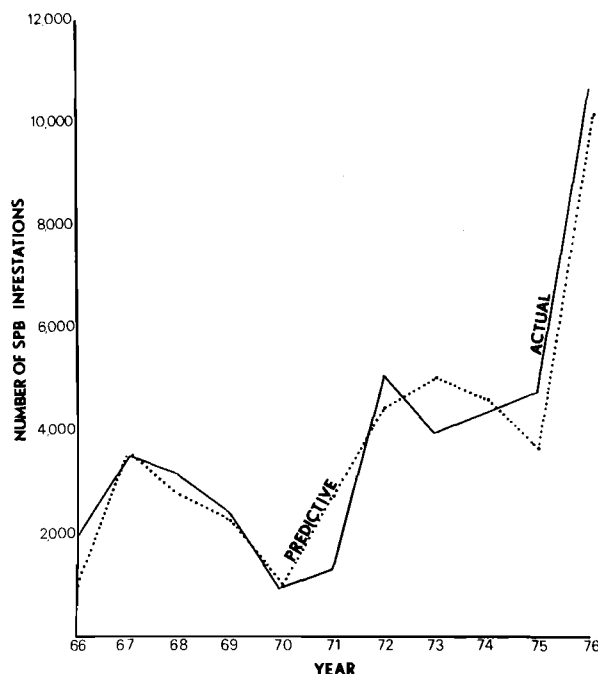


Figure 1. Observed and predicted SPB infestations for east Texas (1966–1976).

The dependent variable was total yearly SPB infestations. Climatic variables for the previous year included total rainfall (in.) (annual and by season), total number of days with rainfall, average seasonal temperatures (°F), and number of days with temperatures above 90°F (30.2°C). The only independent variable for the current year was mean temperature for February. Two inclusion criteria were used in the analysis: minimum F = 1.0; T = 0.30. Minimum F refers to the minimum F-value that the user is willing to accept for variables to be included, while T, or tolerance level, represents the proportion of the variance explained by a particular variable not explained by other independent variables already included in the regression equation.

The 0.05 acceptance level was used throughout this study.

TABLE 2. Regression analysis for number of southern pine beetle spots in east Texas versus climatic variables.

Variable	Multiple r	r ²	r ² -change	Simple r	B	Std Error B	β	F-value
X ₁	0.6712	0.4505	0.4505	0.6712	712.58	107.67	1.0169	43.80**
X ₂	0.7618	0.5803	0.1297	0.4582	462.50	101.95	0.65414	20.58**
X ₃	0.9177	0.8421	0.2618	0.1487	-432.13	98.12	-0.76558	19.39**
X ₄	0.9526	0.9074	0.0653	-0.1490	-121.33	59.00	-0.26114	4.22*
constant					-29864.39			

X₁ = Mean temperature (°F) for February of current year.

X₂ = Total rainfall (in.) for summer of previous year.

X₃ = Total rainfall (in.) for fall of previous year.

X₄ = Total rainfall (in.) for spring of previous year.

** Significant at 0.01 level.

* Significant at 0.05 level.

STEPWISE MULTIPLE REGRESSION

Only four climatic variables were significantly related to numbers of SPB spots (Table 2). These were: (1) mean temperature for February of the current year, (2) total rainfall for the previous summer (June–August), (3) total rainfall for the previous fall (Sept.–Nov.), and (4) total rainfall for the previous spring (March–May). The above variables accounted for 90.7 percent ($r = 0.95$) of the variation in numbers of east Texas beetle infestations. Mean February temperature for the current year explained the largest amount of variation ($r^2 = 0.45$, $r = 0.67$), while total rainfall for summer and fall of the previous year together explained 39.2 percent. Total rainfall for the previous spring had the smallest r^2 -change (0.06). These observations are consistent in part with studies pertaining to limiting climatic factors of SPB.

Extreme winter temperatures certainly have an adverse effect on SPB populations and activity (Flavell *et al.* 1970). The regression analysis suggested that warm February temperatures, prior to spring population growth, have a positive effect on the number of SPB infestations for that year. Cold winter temperatures may slow developmental rates, kill beetles directly, or expose developmental stages to predation.

Several authors (Coster 1977, Kalkstein 1976, 1974, Hansen *et al.* 1974, and King 1972) have commented on the importance of moisture, both in seasonal distribution and abundance, to SPB survival and activity. We found that periods of high summer rainfall were correlated with increased numbers of spots, while high spring and fall rainfall were correlated with decreased infestations. These observations are in contrast to those of King (1972).

APPLICABILITY OF MODEL

The large proportion of variance explained by the regression analysis suggests that the resultant multiple regression model would be a useful predictive tool to anticipate the following season's beetle activity and provide some indication of possible timber losses and manpower needs prior to peak beetle activity. The regression model is represented by the equation,

$$\hat{Y} = 712.58X_1 + 462.50X_2 - 432.13X_3 - 121.33X_4 - 29,864.39$$

$$\hat{Y} = \text{annual total SPB spots } (\geq 10 \text{ trees})$$

$$X_1 = \text{mean February temperature } (^\circ\text{F}) \text{ of current year}$$

$$X_2 = \text{total rainfall (in.) for previous summer (June–August)}$$

$$X_3 = \text{total rainfall for previous fall (Sept.–Nov.)}$$

$$X_4 = \text{total rainfall for previous spring (March–May)}$$

Variables included in the equation are easily obtained from the Stephen F. Austin State University Weather Station or standard weather sources in east Texas. However, we must caution that the regression model is applicable only to east Texas forests; similar southwide studies should be conducted in order to improve the utility of the model. We would further caution that the model does not attempt to predict the degree of SPB activity. Rather it predicts the number of spots, which is certainly an indicator of long-term beetle activity and potential timber loss.

Using the model a prediction for 1976 was 10,161 infestations compared to 10,600 actually observed (Figure 1). We predict that in 1977 there will be approximately 4,200 new SPB infestations in east Texas, a considerable reduction from the 1976 level (*ca.*, 11,000).¹

¹ As of Nov. 1, 1977, approximately 4,400 spots had been reported (Personal Communication, H.A. Pase III, Texas Forest Service, Lufkin, TX).

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