DOUGLAS FIR BEETLE TRAP-SUPPRESSION STUDY

STATISTICAL REPORT

Prepared for

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By

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II. EXECUTIVE SUMMARY

This is a report of the results of statistical analysis of Beetle Suppression data. Questions of interest are defined. The report includes a summary of the project, discussion of the structure of the data and explanatory and response variables, and the statistical procedures employed in the analysis. The data used was provided by Dr. Rob Progar, USDA Forest Service PNW Research Station, Corvallis, Oregon.

Results are reported in two chapters, Pre-Treatment and Post-Treatment analyses. A list of Literature Cited is included in the last chapter. S-Plus commands and bench notes are included on the enclosed CD for further information and clarification of the analyses. Excel data and table files are also provided on the enclosed CD. This work is in partial fulfillment of USDA Purchase Order Number 43-04R4-4-0058.

III. INTRODUCTION

Summary of the experiment and objectives

In 2004 an experiment was conducted to determine if reducing the number of Douglas Fir beetles in stands by trapping would reduce the number of trees killed by the beetles. In forests at each of two localities in Montana (Phillipsburg and Wisdom) six 2-acre plots were established to monitor tree mortality due to beetle attack. Treatments were assigned at random to the plots. On the perimeter of the three of the treatment plots at each locality, nine traps were established (in groups of three). No traps were set at the control plots. Traps were opened over the course of one field season, and the number of trees on each plot were classified into one of six status-categories.

Pacific Analytics received the raw data in Excel spreadsheets during an initial consultation with the client in December 2004. The primary assigned tasks were to compile the data for evaluation, and to estimate the effects of beetle suppression on tree mortality.

The structure of this study is a completely randomized design. The experimental units for testing Treatment level effects are the plots on which measurements were made.

Primary Questions of Interest

1. Does trapping reduce the proportion of available trees that die (Code 2 trees) due to beetle attack?

2. Does trapping reduce the proportion of available trees attacked by beetles (Code 2 and Code 5 trees)?

3. Is there a relationship between the number of Douglas Fir Beetles and the number of red-legged Clarid beetles?

4. Is there a relationship between the number of Douglas Fir Beetles and the proportion of available trees attacked by beetles (Code 2 and Code 5 trees)?

5. Is there a relationship between the number of Douglas Fir Beetles and the proportion of available trees that die due to beetle attack (Code 2 trees)?

Population of Interest

The proportion of available trees on two-acre plots that died from beetle attack (Code 2 trees).

The proportion of available trees on two-acre plots that were attacked by beetles (Code 2 and Code 5 trees).

The number of red-legged Clarid beetles per treatment plot

The number of Douglas Fir beetles per treatment plot

Structure of the Experiment

Experimental Units

Experimental units are 2-acre plots at each locality.

Response variables

The proportion of trees on two-acre plots that died from beetle attack.

ANOVA Tables

Without Covariates

Source of Variation	Degrees of Freedom
Locality	1
Site	4
Treatments	1
Experimental Error	5

With Covariates

Source of Variation	Degrees of Freedom
Locality	1
Site	4
Covariate 1	1
Covariate 2	1
Treatments	1
Experimental Error	3

IV. Statistical Procedures

Data Compilation

Data compilation was conducted using Excel spreadsheet commands. The proportion for each category of Tree Code (0 – 5) were calculated based on the number of trees in that Code Class divided by the number of available trees (Code 0 + Code 2 + Code 5 trees).

Proportion data were transformed using the arc sin square root transformation before analysis with ANOVA (Sokal and Rohlf 1981).

Analysis of Variance

Analysis of Variance is a statistical method used to analyze independent samples from three or more treatment groups. The method uses the *F-test* to answer the question "Are all of the treatment group means equal?" The *F-test* is based on residuals, the difference between the hypothesized value and the observed value. Residuals represent the variability in the observations unexplained by a model. The *F-test* compares the sum of squared residuals from a reduced (equal means) model to the sum of squared residuals from a full (separate means) model.

The reduced model residuals were derived by subtracting the observed (measured) values from the grand mean for all observations. These residuals are squared and summed to obtain the *sum of squared residuals (reduced)*. This value is also known as the Total variation or *error*. The full model residuals are derived by subtracting the observed (measured) values from mean of the treatment group to which it was assigned. These residuals are squared and summed to obtain the *sum of squared residuals (full)*. This value is also known as the Within Groups variation. The difference between the *sum of squared residuals (reduced)* and the *sum of squared residuals (full)* is called the *extra sum of squares*, also known as the Between Groups variation.

The *F-statistic* is the ratio of the average Between Groups variation (*extra sum of squares divided by the degrees of freedom*) and the Total variation. This ratio has an *F-distribution* that depends on two known parameters, the numerator degrees of freedom and the denominator degrees of freedom. The *p-value* obtained represents the strength of the evidence against the equal means model and in favor of the model with separate means.

The assumptions of ANOVA are the same as those for many of the other standard statistical methods. Analysis of Variance is based on the normal (Gaussian) probability distribution, although this assumption is not critical unless the distributions of the data are extremely long-tailed and sample sizes are unequal. The method strictly relies on the assumption of independence of the observations, and random assignment of sampling units to treatment groups. The assumption of equal variance between groups is crucial, but ANOVA is robust to departures of variance equality when sample sizes are equal. Finally, outliers in the data can influence the results of ANOVA.

Software used for all statistical analyses was S-Plus 2000 (MathSoft 1988-1999).

V. PRETREATMENT ANOVA

NUMBER OF TREES PER PLOT

Analysis of Variance (ANOVA) was used to test for pretreatment differences in the number of trees per 2-acre plot between treatments and control plots. Site and Locality were used as a blocking factors.

ANOVA Table

SOV	DF	Sum of Squares	Mean Squares	F Values	P-Values
Locality	1	109634.1	109634.1	9.942075	0.0253
Site	4	121115.7	30278.9	2.745818	0.1488
Treatment	1	12224.1	12224.1	1.108531	0.3406
Error	5	55136.4	11027.3		

Statistical Inference

There is no evidence of a difference in the number of trees per 2-acre plot between treatment and control plots (p-value = 0.3406). The control plots averaged 233 (±38.2) trees per 2-acre plot and the treatment plots averaged 297 (±89.8) trees per 2-acre plot.

There is evidence that the Phillipsburg locality had a higher number of trees per 2-acre plot than Wisdom locality (p-value = 0.0253). The 2-acre plots in Phillipsburg had a average of 361 (±77.3) trees per 2-acre plot and the Wisdom plots had an average of 170 (±17.5) trees per 2-acre plot.

VI. POST-TREATMENT ANALYSIS

CODE 2 TREES

Analysis of Variance was used to test for a difference in the proportion of Code 2 trees per 2-acre plot between treatment and control plots. An arcsin square root transformation was applied to the proportion data for the analysis. Locality and site were used as blocking factors.

ANOVA Table

SOV	DF	Sum of Squares	Mean Squares	F Values	P-Values
Locality	1	0.04826496	0.04826496	2.571812	0.1697
Site	4	0.09622009	0.02405502	1.281779	0.3881
Treatment	1	0.00760855	0.00760855	0.405424	0.5523
Error	5	0.09383454	0.01876691		

Statistical Inference

There is no evidence of a difference in the median proportion of Code 2 trees per 2-acre plot between treatment and control plots (p-value = 0.5523). The median proportion of Code 2 trees on control plots was 0.08 (±0.001) trees per 2-acre plot and the median proportion of Code 2 trees on treatment plots was 0.11 (±0.007) trees per 2-acre plot.

CODE 2 TREES WITH COVARIATES

Analysis of Variance was used to test for a difference in the proportion of Code 2 trees per 2-acre plot between treatment and control plots. An arcsin square root transformation was applied to the proportion data for the analysis. Locality and site were used as blocking factors. The proportion of Code 0 and Code 3 trees (arcsin square root transformed) were used as covariates in the ANOVA models. The covariates were placed in the model after accounting first for Locality and Site variations but before accounting for Treatment variation.

ANOVA Table

SOV	DF	Sum of Squares	Mean Squares	F Values	P-Values
Locality	1	0.04826496	0.04826496	27.42496	0.0136
Site	4	0.09622009	0.02405502	13.66847	0.0287
Code 0	1	0.08446699	0.08446699	47.99556	0.0062
Code 3	1	0.0000032	0.0000032	0.00182	0.9687
Treatment	1	0.01169322	0.01169322	6.64428	0.0819
Error	3	0.00527967	0.00175989		

Statistical Inference

There is suggestive evidence of a difference in the median proportion of Code 2 trees per 2-acre plot between treatment and control plots after accounting for the proportions of Code 0 and Code 3 trees per plot (p-value = 0.0819). The median proportion of Code 2 trees on control plots was 0.08 (±0.001) trees per 2-acre plot and the median proportion of Code 2 trees on treatment plots was 0.11 (±0.007) trees per 2-acre plot.

CODE 3 TREES

Analysis of Variance was used to test for a difference in the proportion of Code 3 trees per 2-acre plot between treatment and control plots. An arcsin square root transformation was applied to the proportion data for the analysis. Locality and site were used as blocking factors.

ANOVA Table

SOV	DF	Sum of Squares	Mean Squares	F Values	P-Values
Locality	1	0.00609746	0.00609746	0.625542	0.4648
Site	4	0.03930021	0.00982505	1.007958	0.4825
Treatment	1	0.02534639	0.02534639	2.600302	0.1678
Error	5	0.04873739	0.00974748		

Statistical Inference

There is no evidence of a difference in the median proportion of Code 3 trees per 2-acre plot between treatment and control plots (p-value = 0.1678). The median proportion of Code 3 trees on control plots was 0.10 (±0.002) trees per 2-acre plot and the median proportion of Code 3 trees on treatment plots was 0.05 (±0.001) trees per 2-acre plot.

CODE 2 and 5 TREES

Analysis of Variance was used to test for a difference in the combined proportion of Code 2 and Code 5 trees per 2-acre plot between treatment and control plots. An arcsin square root transformation was applied to the proportion data for the analysis. Locality and site were used as blocking factors.

ANOVA Table

SOV	DF	Sum of Squares	Mean Squares	F Values	P-Values
Locality	1	0.0925948	0.09259483	3.291138	0.1294
Site	4	0.1424617	0.03561541	1.265894	0.3929
Treatment	1	0.060232	0.060232	2.140852	0.2033
Error	5	0.140673	0.02813459		

Statistical Inference

There is no evidence of a difference in the median combined proportion of Code 2 and Code 5 trees per 2-acre plot between treatment and control plots (p-value = 0.2033). The median combined proportion of Code 2 and Code 5 trees on control plots was 0.11 (±0.002) trees per 2-acre plot and the median proportion of Code 3 trees on treatment plots was 0.22 (±0.01) trees per 2-acre plot.

NUMBER OF BEETLES AND TREES ATTACKED

Regression was used to test for a significant relationship between the proportion of Code 2 trees per 2-acre plot and the number of Douglas Fir beetles captured on treatment plots. An arcsin square root transformation was applied to the proportion data for the analysis. The beetle count data were transformed using a natural logarithm transformation. Locality was used as blocking factor.

Regression Table

SOV	Coefficient	Standard Error	t-value	P-value
Intercept	1.59	3.8958	0.4073	0.7111
Locality	-0.33	0.2201	-1.4848	0.2343
Beetles	-0.09	0.3066	-0.2867	0.7930

Statistical Inference

There is no evidence of a relationship between the median proportion of Code 2 trees per 2-acre plot and the median number of beetles captured per plot (p-value = 0.7930).

NUMBER OF BEETLES AND TREES ATTACKED

Regression was used to test for a significant relationship between the combined proportion of Code 2 and Code 5 trees per 2-acre plot and the number of Douglas Fir beetles captured on treatment plots. An arcsin square root transformation was applied to the proportion data for the analysis. The beetle count data were transformed using a natural logarithm transformation. Locality was used as blocking factor.

Regression Table

SOV	Coefficient	Standard Error	t-value	P-value
Intercept	5.03	3.7076	1.3578	0.2676
Locality	-0.55	0.2095	-2.6366	0.0779
Beetles	-0.34	0.2918	-1.179	0.3234

Statistical Inference

There is no evidence of a relationship between the median combined proportion of Code 2 and Code 5 trees per 2-acre plot and the median number of beetles captured per plot (p-value = 0.3234).

NUMBER OF DOUGLAS FIR BEETLES AND RED-LEGGED CLARID BEETLES

Regression was used to test for a significant relationship between the number of red-legged Clarid beetles and the number of Douglas Fir beetles captured on treatment plots. The beetle count data were transformed using a natural logarithm transformation. Locality was used as blocking factor.

Regression Table

SOV	Coefficient	Standard Error	t-value	P-value
Intercept	8.38	12.6321	0.6636	0.5544
Locality	-0.03	0.7138	-0.0466	0.9658
Beetles	0.03	0.9943	0.0323	0.9763

Statistical Inference

There is no evidence of a relationship between the median number of red-legged Clarid beetles and the median number of beetles captured per plot (p-value = 0.9763).

VII. LITERATURE CITED

Sokal, R.R. and F.J. Rohlf. 1981. Biometry, Second Edition. W.H. Freeman and Company, New York. 859 pp.

S-Plus 2000. 1988-1999. Data Analysis Products Division, MathSoft, Seattle, WA.