

**VARIANCE COMPONENTS OF FIVE SAMPLING METHODS
FOR DETECTING POPULATION CHANGES OF
NON-TARGET ARTHROPODS**

STATISTICAL REPORT

Prepared for

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By



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Executive Summary**
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II. EXECUTIVE SUMMARY

This is a report of the results of statistical analysis of arthropod trapping 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 six chapters, arranged by collecting method. Each chapter includes results of Components of Variance calculations using maximum likelihood (ML) and restricted maximum likelihood estimates (REML). It is recommended for future publications that the client use the REML estimates for reasons discussed in the Chapter IV. Statistical Procedures.

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.

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III. INTRODUCTION

Summary of the experiment and objectives

In 1992 an experiment was started to study the effects of two different treatment used to control gypsy moth (*Lymantria dispar*). Within the context of this study non-target arthropods were collected using five sampling methods, foliage pruning, canvas banding, pitfall trapping, light trapping, and Malaise trapping. Three sites of gypsy moth defoliation were selected for study. One site was treated with *Bacillus thuringiensis* (B.T.), one with diflubenzuron, and one was used as a control. Three sampling locations were selected within each of the three sites and arthropods were collected with the five sampling methods weekly from early May until mid-August for three years, 1992, 1993, and 1994.

The objective was to test the effectiveness of the two gypsy moth control treatments, and to evaluate the effects of the treatments on non-target arthropods. A second objective was to estimate the components of variance and use them make inferences about the optimum number of measurements to take from each experimental unit, and evaluate the efficiency of the five sampling methods using cost/benefit analysis for future experiments and studies.

Pacific Analytics received the raw data in Excel spreadsheets during an initial consultation with the client in August 2004. The primary assigned tasks were to compile the data into several taxa and sampling method data sets for evaluation, and to estimate the components of variance for each of the data sets.

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Primary Questions of Interest

1. What are the components of variance for eight taxa groups of arthropods collected from foliage?
2. What are the components of variance for ten taxa groups of arthropods collected with canvas bands?
3. What are the components of variance for four taxa groups of arthropods collected with pitfall traps?
4. What are the components of variance for seven taxa groups of arthropods collected with light traps?
5. What are the components of variance for nine taxa groups of arthropods collected with Malaise traps?

Populations of Interest

1. Taxa abundance of arthropods collected from foliage pruning,
2. Foliage pruning sample arthropod species richness,
3. Taxa abundance of arthropods collected with canvas bands,
4. Canvas band sample arthropod species richness,
5. Taxa abundance of arthropods collected with pitfall traps,
6. Pitfall trap sample arthropod species richness,
7. Taxa abundance of arthropods collected with light traps,
8. Light traps sample arthropod species richness,
9. Taxa abundance of arthropods collected with Malaise traps,
10. Malaise traps sample arthropod species richness,

Structure of the Experiment

Experimental Units

Experimental units are sites (within treatment areas that received one of the gypsy moth control treatments).

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Treatment Areas each received one of the Gypsy moth control treatments (*Bacillus thuringiensis* (B.T.), diflubenzuron, and no treatment). The treatments were assigned at random to the Treatment Areas and are considered as fixed-effects when there are more than one sample or trap per Site. A factor is fixed if its *levels* are selected by a nonrandom process (Milliken and Johnson 1992). In this study only the effects of the two Gypsy moth control treatments were of interest, and are therefore fixed-effects. In order to estimate components of variance, Treatment Areas must be considered as random when there is only one trap per Site.

Within each of the three treatment areas, three sampling sites were randomly chosen, based on similar composition of dominant oak canopy and maple understory vegetation. Because the Sites were chosen at random from a population of available sites, their effects are considered random. A factor is considered random if its levels consist of a random sample of levels from a population of possible levels (Milliken and Johnson 1992).

Weekly from early May until mid-August at each of the three sampling sites within each of the three treatment areas:

Arthropods were collected from two foliage samples consisting of about 25 branch tips from randomly selected oak trees,

Arthropods were collected from two foliage samples consisting of about 25 branch tips from randomly selected maple trees,

Arthropods were collected from canvas bands placed at breast height on 10 random oak trees

Arthropods were collected from nine 16 oz. pitfall traps placed in a 3x3 grid,

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Adult macrolepidoptera were collected from one light trap placed 3 meters from the ground and run for one night per week,

Arthropods were collected from one Malaise trap.

Sampling was conducted in 1992, 1993, and 1994.

Response variables

Number of arthropods from selected taxa in each sample from each of the five sampling methods pooled over the entire sampling year. Each observation consists of the taxon abundance (counts) that are the sum of individuals in that taxon collected over 15 weeks of sampling by treatment area, site, and sample (or trap).

Number of arthropod species from selected taxa in each sample from each of the five sampling methods pooled over the entire sampling year. Each observation consists of the number (counts) of taxa collected over 15 weeks of sampling by treatment area, site, and sample (or trap).

Arthropod abundance is the count of occurrences of individuals of taxa collected by the sampling methods. The counts have no definite upper bound because the maximum number of captures is limited to an unknown quantity, the number of individuals within the range of the sampling method. The *Poisson probability distribution* is often used to describe the population distribution of counts (Ramsey and Schafer 1997).

$$count_{ijk} \sim \text{Poisson} (\mu_{ijk})$$

For statistical analysis, the log of the mean is modeled as linear in the effects (explanatory or independent variables). The analysis can be conducted as a generalized linear model, using Poisson analysis of variance or regression (Ramsey and Schafer 1997). As an alternative, the response variable is transformed using the log transformation to stabilize the variance and normal ANOVA procedures can be applied (Sokal and Rohlf (1981).

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When there are several samples or traps (replicates) within each Site, the model for the response variable for Treatment Area (TA), Site (S), and replicate is:

$$\log(\mu_{ijk}) = \text{mean} + \xi_i + \beta_{ij} + \varepsilon_{ijk}$$

where ξ is the fixed effect of Treatment Area, and β and ε are independent random variables with zero means and variances; σ_S^2 (variance of Sites within Treatment Areas) and σ_R^2 (variance of replicates) respectively (Montgomery 1991)

When there is only one trap per Site, the model for the response variable for Treatment Area (TA) and Site (S) (= trap), is:

$$\log(\mu_{ijk}) = \text{mean} + \xi_i + \varepsilon_{ij}$$

where μ is the grand mean, and ξ and ε are independent random variables with zero means and variances; σ_{TA}^2 (variance of Treatment Areas) and σ_T^2 (variance of traps) respectively (Montgomery 1991).

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IV. Statistical Procedures

Data Compilation

Data compilation was conducted using Excel spreadsheet commands.

Foliage Sample Data

The data for arthropods collected from foliage pruning were received in four spreadsheets, FolMacOaks.xls, FolMacMaple.xls, FolTaxaOak.xls, and FolTaxaMaple.xls. Each of the spreadsheets was compiled by first sorting by year and then separating them each into 3 separate yearly data sets. The yearly data sets were sorted by Treatment Area, Site, and Sample and subtotaled (summed) each sample at each site in each treatment area. The results were data sets for each of the three years containing a total abundance for each taxon in each sample over the sampling dates for each year.

Using the COUNTIF() command, the number of columns containing a number greater than zero were counted for each sample record (row) at each site in each treatment area. This provided the species richness response variable. Using the SUM() command, the total arthropod (or macrolepidoptera) abundance was derived for each sample record (row) at each site in each treatment area. In the macrolepidoptera data set a new response variable was created by subtracting the abundance of gypsy moths in each record.

Finally, the data were transformed using the natural log transformation, $\ln(y + 0.01)$. The compiled yearly data are contained in six spreadsheets. Maple sample data are in MYEAR1, MYEAR2, and MYEAR3, and Oak sample data are in OYEAR1, OYEAR2, and OYEAR3.

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Canvas Band Sample Data

The data for arthropods collected from canvas bands were received in two spreadsheets, bandmaclep.xls and bandsaxa_all.xls. Each of the spreadsheets was compiled by first sorting by year and then separating them each into 3 separate yearly data sets. The yearly data sets were sorted by Treatment Area, Site, and Band and subtotaled (summed) for every band at each site in each treatment area. The results were data sets containing a total for each taxon in each band over the sampling dates for each year.

Using the COUNTIF() command, the number of columns containing a number greater than zero were counted for each band record (row). This provided the species richness response variable. Using the SUM() command, the total arthropod (or macrolepidoptera) abundance was derived for each band record (row) at each site in each treatment area. In the macrolepidoptera data set a new response variable was created by subtracting the abundance of gypsy moths in each record.

Finally, the data were transformed using the natural log transformation, $\ln(y + 0.01)$. The compiled yearly data are contained in three spreadsheets; BYEAR1, BYEAR2, and BYEAR3.

Pitfall Trap Data

The data for arthropods collected from pitfall traps were received in one spreadsheet, Pitfall_Taxa.xls. The spreadsheet was compiled by first sorting by year and then separating it into 3 separate yearly data sets. The yearly data sets were sorted by Treatment Area, Site, and Pit and subtotaled (summed) for each pitfall trap at each site in each treatment

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area. The results were data sets containing a total for each taxon in each pitfall trap over the sampling dates for each year.

Using the COUNTIF() command, the number of columns containing a number greater than zero were counted for each pitfall trap record (row). This provided the species richness response variable. Using the SUM() command, the total arthropod abundance was derived for each pitfall trap record (row) at each site in each treatment area.

Finally, the data were transformed using the natural log transformation, $\ln(y + 0.01)$. The compiled yearly data are contained in three spreadsheets; PYEAR1, PYEAR2, and PYEAR3.

Light Trap Sample Data

The data for macrolepidoptera collected from light traps were received in four spreadsheets, LightTrap92.xls, LightTrap93_1.xls, LightTrap93_2.xls, and LightTrap94.xls. The data sets were sorted by Treatment Area and Site and subtotaled (summed) for each Site within each treatment area. The results were data sets containing a total for each taxon in each light trap over the sampling dates for each year.

Using the COUNTIF() command, the number of columns containing a number greater than zero were counted for each light trap record (row). This provided the species richness response variable. Using the SUM() command, the total macrolepidoptera abundance was derived for each light trap record (row) at each site within each treatment area. In the macrolepidoptera data set a new response variable was created by subtracting the abundance of gypsy moths in each record. The 1993 data set was too large for one spreadsheet and was divided into two

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spreadsheets. The species richness and abundance for 1993 was obtained by adding the results from the two larger spreadsheets.

Finally, the data were transformed using the natural log transformation, $\ln(y + 0.01)$. The compiled yearly data are contained in three spreadsheets; LYEAR1, LYEAR2, and LYEAR3.

Malaise Trap Sample Data

The data for arthropods collected from Malaise traps were received in two spreadsheets, MalaisMac.xls and MalaisTaxa.xls. The spreadsheets were compiled by first sorting by year and then separating each into 3 separate yearly data sets. The yearly data sets were sorted by Treatment Area and Site and subtotaled (summed) for each Malaise trap at each site within each treatment area. The results were data sets containing a total for each taxon in each Malaise trap over the sampling dates for each of the years.

Using the COUNTIF() command, the number of columns containing a number greater than zero were counted for each Malaise trap record (row). This provided the species richness response variable. Using the SUM() command, the total arthropod (or macrolepidoptera) abundance was derived for each Malaise trap record (row) at each site within each treatment area. In the macrolepidoptera data set a new response variable was created by subtracting the abundance of gypsy moths in each record.

Finally, the data were transformed using the natural log transformation, $\ln(y + 0.01)$. The compiled yearly data are contained in three spreadsheets; MYEAR1, MYEAR2, and MYEAR3.

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Estimation of Components of Variance

Variance components models are used when there is interest in variability of one or more variables other than the residual error. One of the goals of this study was to estimate components of variation that could be used to compute efficiency of the five arthropod sampling methods.

As discussed above (page 7), the variance components of interest when there are several samples or traps per Site are

$$\sigma_s^2 \text{ (Variance of Sites within Treatment Areas)}$$

$$\sigma_r^2 \text{ (Variance of traps)}$$

When there is only one trap per Site, , the variance components of interest are

$$\sigma_{TA}^2 \text{ (variance of Treatment Areas)}$$

$$\sigma_T^2 \text{ (Variance of traps)}$$

The following Analysis of Variance tables illustrate the components of variance and their sources.

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Foliage Samples

The Analysis of Variance table for t Treatment Areas (TA), s Sites (S) per Treatment Area, and n foliage samples (replicates) per site in a nested design is:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Expected, E(MS). Mean Square
Between Treatment Areas	$t-1$	NA	MS_{TA}	NA
Sites Within Treatment Areas	$t(s-1)$	$n \sum_{ij} (\bar{y}_{ij} - \bar{y}_i)^2$	MS_{Site}	$n \sigma_S^2 + \sigma_R^2$
Foliage Samples Within Sites	$ts(n-1)$	$\sum_{ijk} (y_{ijk} - \bar{y}_{ij})^2$	$MS_{replicate}$	σ_R^2

(Note: Means Squares are the Sum of Squares divided by the degrees of freedom)

And the unbiased estimators of the variance components are:

$$\text{Variance for Replicates (foliage samples) within Sites} = \hat{\sigma}_R^2 = MS_{replicate}$$

$$\text{Variance for Sites within Treatment Areas} = \hat{\sigma}_S^2 = (MS_{Site} - \hat{\sigma}_R^2) / n$$

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Canvas Bands

The Analysis of Variance table for t Treatment Areas (TA), s Sites (S) per Treatment Area, and n canvas bands (replicates) per site in a nested design is:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Expected, E(MS). Mean Square
Between Treatment Areas	$t-1$	NA	MS_{TA}	NA
Sites Within Treatment Areas	$t(s-1)$	$n \sum_{ij} (\bar{y}_{ij} - \bar{y}_i)^2$	MS_{Site}	$n \sigma_S^2 + \sigma_R^2$
Canvas bands Within Sites	$ts(n-1)$	$\sum_{ijk} (y_{ijk} - \bar{y}_{ij})^2$	$MS_{replicate}$	σ_R^2

(Note: Means Squares are the Sum of Squares divided by the degrees of freedom)

And the unbiased estimators of the variance components are:

$$\text{Variance for Replicates (canvas bands) within Sites} = \hat{\sigma}_R^2 = MS_{replicate}$$

$$\text{Variance for Sites within Treatment Areas} = \hat{\sigma}_S^2 = (MS_{Site} - \hat{\sigma}_R^2) / n$$

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Pitfall Traps

The Analysis of Variance table for t Treatment Areas (TA), s Sites (S) per Treatment Area, and n pitfall traps (replicates) per site in a nested design is:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Expected, E(MS). Mean Square
Between Treatment Areas	$t-1$	NA	MS_{TA}	NA
Sites Within Treatment Areas	$t(s-1)$	$n \sum_{ij} (\bar{y}_{ij} - \bar{y}_i)^2$	MS_{Site}	$n \sigma_S^2 + \sigma_R^2$
Canvas bands Within Sites	$ts(n-1)$	$\sum_{ijk} (y_{ijk} - \bar{y}_{ij})^2$	$MS_{replicate}$	σ_R^2

(Note: Means Squares are the Sum of Squares divided by the degrees of freedom)

And the unbiased estimators of the variance components are:

$$\text{Variance for Replicates (pitfall traps) within Sites} = \hat{\sigma}_R^2 = MS_{replicate}$$

$$\text{Variance for Sites within Treatment Areas} = \hat{\sigma}_S^2 = (MS_{Site} - \hat{\sigma}_R^2) / n$$

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Malaise Traps and Light Traps

The Analysis of Variance table for t Treatment Areas (TA), s Sites (S) within each Treatment Area, and 1 Malaise or Light Trap per Site in a nested design is:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Expected, E(MS). Mean Square
Between				
Treatment Areas	$t-1$	$s \sum_i (\bar{y}_i - \bar{y})^2$	MS_{TA}	$s \sigma_{TA}^2 + \sigma_T^2$
Traps (Sites) Within				
Treatment Areas	$t(s-1)$	$\sum_i (y_i - \bar{y}_i)^2$	MS_{Trap}	σ_T^2

(Note: Means Squares are the Sum of Squares divided by the degrees of freedom)

And the unbiased estimators of the variance components are:

$$\text{Variance for Sites (Traps) within Treatment Areas} = \hat{\sigma}_T^2 = MS_{Trap}$$

$$\text{Variance for Treatment Areas} = \hat{\sigma}_{TA}^2 = (MS_{TA} - MS_{Trap})/3$$

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The results of estimates of the components of variance are presented in tables such as this:

	Variance of Sites	Variance of Traps
1992	$\hat{\sigma}_{S1}^2$	$\hat{\sigma}_{R1}^2$
1993	$\hat{\sigma}_{S2}^2$	$\hat{\sigma}_{R2}^2$
1994	$\hat{\sigma}_{S3}^2$	$\hat{\sigma}_{R3}^2$
3-Year Average	$\hat{\sigma}_{SMEAN}^2$	$\hat{\sigma}_{RMEAN}^2$

Where $\hat{\sigma}_{S1}^2$, $\hat{\sigma}_{S2}^2$, $\hat{\sigma}_{S3}^2$ are the estimated variances of Sites within Treatment Areas for years 1, 2, and 3 respectively, and $\hat{\sigma}_{SMEAN}^2$ is the average of the estimated variances for the 3 years, and $\hat{\sigma}_{R1}^2$, $\hat{\sigma}_{R2}^2$, $\hat{\sigma}_{R3}^2$ are the estimated variances of Traps (or Foliage Samples) for years 1, 2, and 3 respectively, and $\hat{\sigma}_{RMEAN}^2$ is the average of the estimated variances for the 3 years.

The variance components estimated using the formulas above should theoretically be nonnegative because they are assumed to represent the variance of a random variable. Nevertheless, when using the methods above, some estimates of variance components may become negative (Freund et al., 1991).

Negative estimates may arise for a variety of reasons. When the variability in the replicates (trap samples within a site) is large enough, a negative estimate may result, even though the true value of the variance component is positive. Sometimes the data may contain outliers, increasing the replicate variation and leading to negative variance estimates (Hocking 1984). Negative variance

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estimates also arise when an inappropriate model is used for interpreting the data. A transformation (such as a log or square root transformation in the case of count data) may correct this problem. In addition, under some statistical models for variance components analysis, negative estimates are an indication that observations in your data are negatively correlated. Special consideration must always be made to use the appropriate model or data transformation for analysis.

Most of the time, negative variance components indicate an absence of systematic structure. They can have a biological meaning, though. For instance samples from different Treatment Areas can be more similar to each other than samples from the same Treatment Area. This can be the result of clumped (negative binomially distributed) arthropods, a condition that is expected when food resources are scarce or when adults are seeking mating partners. It could also mean that the sampling method does not adequately measure the population of interest.

If one is satisfied that the model is correct, it is common practice to treat negative variance components as if they are zero. However, negative variances are not acceptable when comparing the efficiencies of several sampling methods. More robust methods are available to estimate components of variance. Considerable attention has been paid to developing methods that provide positive estimators (Thompson 1962, Patterson and Thompson 1971, 1975, Searle 1971, Harville 1977, Searle et al. 1992). Two popular methods rely on maximum likelihood and restricted maximum likelihood estimators for components of variance (Harville 1977, Venables and Ripley 1994). Due to the nature of the algorithms used for maximum likelihood and restricted maximum likelihood methods, negative estimates are constrained to zero.

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The maximum likelihood process uses the assumed distribution of the observations and constructs a likelihood function, which is a function of the model parameters (Milliken and Johnson 1992). The maximum likelihood (ML) method makes use of a Newton-Raphson computing algorithm that iterates until the log-likelihood objective function converges (Searle et al. 1992). The maximum likelihood estimators that result are those values of the parameters from the parameter space that maximize the value of the likelihood function (Milliken and Johnson 1992). The restricted maximum likelihood method (REML) is similar to the maximum likelihood method, but it first separates the likelihood into two parts; one that contains the fixed effects and one that does not (Patterson and Thompson 1971). Bias due to the fixed effects is removed and estimates of variance components are calculated only for the random effects (Gould and Nichols 1998). A brief review of the restricted maximum likelihood estimators appears in Anderson et al. (1986).

The choice of using either the ML method versus REML method has been discussed in the literature (Harville 1977, Searle et al. 1992, Gould and Nichols 1998). Each has its own advantages and disadvantages. Both were used for this report for comparison by the client. After studying the literature, it is recommended that for publication, the components of variance derived using the REML method be used because it removes the bias due to fixed effects and appears more frequently in the literature (Searle et al. 1992).

For the tasks presented in this report, both maximum likelihood and restricted maximum likelihood estimators were obtained for each of the yearly data sets on the natural log transformed data using the transformation formula

$$\ln(y + 0.01)$$

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Three year averages of variance components for each taxon are also reported. Software used for all statistical analyses was S-Plus 2000 (MathSoft 1988-1999).



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 Oak Foliage Sample Data**
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V. VARIANCE COMPONENTS OF OAK SAMPLE DATA

ELATERIDAE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.2413
1993	0.0000	10.0181
1994	0.0100	0.1362
3-Year Average	0.0033	3.4652

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0135	0.2787
1993	2.2922	10.1880
1994	0.0490	0.1362
3-Year Average	0.7849	3.5343

CURCULIONIDAE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0769	0.0594
1993	0.0000	0.1752
1994	0.0402	0.1473
3-Year Average	0.0390	0.1273

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.1301	0.0594
1993	0.0154	0.1979
1994	0.0972	0.1473
3-Year Average	0.0809	0.1349



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GRYLLIDAE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0734	0.0688
1993	0.0006	0.3886
1994	0.0000	3.7902
3-Year Average	0.0247	1.4159

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.1273	0.0688
1993	0.0981	0.3886
1994	0.8970	3.8306
3-Year Average	0.3741	1.4294

ARTHROPOD RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0019	0.0073
1993	0.0019	0.0117
1994	0.0079	0.0033
3-Year Average	0.0039	0.0074

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0046	0.0073
1993	0.0057	0.0117
1994	0.0126	0.0033
3-Year Average	0.0076	0.0074

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ARTHROPOD ABUNDANCE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0047	0.0300
1993	0.0226	0.0263
1994	0.0000	0.0211
3-Year Average	0.0091	0.0258

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0145	0.0300
1993	0.0404	0.0263
1994	0.0046	0.0216
3-Year Average	0.0198	0.0260

MACROLEPIDOPTERA RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0348
1993	0.0024	0.0474
1994	0.0000	0.0421
3-Year Average	0.0008	0.0414

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0418
1993	0.0155	0.0474
1994	0.0000	0.0505
3-Year Average	0.0052	0.0465

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MACROLEPIDOPTERA ABUNDANCE WITH GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0954
1993	0.0496	0.0646
1994	0.0000	0.2917
3-Year Average	0.0165	0.1505

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.1144
1993	0.0905	0.0646
1994	0.0000	0.3500
3-Year Average	0.0302	0.1764

MACROLEPIDOPTERA ABUNDANCE WITHOUT GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.1795
1993	0.0429	0.1228
1994	0.0000	0.6690
3-Year Average	0.0143	0.3238

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.2154
1993	0.0951	0.1228
1994	0.0000	0.8028
3-Year Average	0.0317	0.3803

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Maple Foliage Sample Data**
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VI. VARIANCE COMPONENTS OF MAPLE SAMPLE DATA

ELATERIDAE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.1456
1993	0.0000	13.5636
1994	0.0000	0.1896
3-Year Average	0.0000	4.6329

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.1748
1993	0.0000	16.2763
1994	0.0196	0.2119
3-Year Average	0.0065	5.5543

CURCULIONIDAE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	8.5867
1993	0.1113	0.1711
1994	0.0981	0.1197
3-Year Average	0.0698	2.9592

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	10.3045
1993	0.2097	0.1711
1994	0.1770	0.1197
3-Year Average	0.1289	3.5318

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Maple Foliage Sample Data**
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GRYLLIDAE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	4.2805
1993	3.2539	8.4469
1994	6.5863	2.7389
3-Year Average	3.2800	5.1554

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	5.1367
1993	6.9925	8.4469
1994	10.5641	2.7389
3-Year Average	5.8522	5.4408

ARTHROPOD RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0024	0.0101
1993	0.0000	0.0115
1994	0.0000	0.0083
3-Year Average	0.0008	0.0100

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0062	0.0101
1993	0.0013	0.0128
1994	0.0000	0.0100
3-Year Average	0.0025	0.0110

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Maple Foliage Sample Data**

ARTHROPOD ABUNDANCE

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0434	0.0236
1993	0.0076	0.0914
1994	0.0025	0.0216
3-Year Average	0.0178	0.0455

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0710	0.0236
1993	0.0343	0.0914
1994	0.0091	0.0216
3-Year Average	0.0381	0.0455

MACROLEPIDOPTERA RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0259
1993	0.0000	0.0377
1994	0.0000	0.1115
3-Year Average	0.0000	0.0584

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0311
1993	0.0000	0.0453
1994	0.0000	0.1337
3-Year Average	0.0000	0.0700

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Maple Foliage Sample Data**

MACROLEPIDOPTERA ABUNDANCE WITH GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0567
1993	0.0000	0.0629
1994	0.0000	0.1361
3-Year Average	0.0000	0.0852

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0680
1993	0.0000	0.0755
1994	0.0000	0.1633
3-Year Average	0.0000	0.1022

MACROLEPIDOPTERA ABUNDANCE WITHOUT GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0579
1993	0.0000	0.0524
1994	0.0000	0.4819
3-Year Average	0.0000	0.1974

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Sites	Variance of Foliage Samples
1992	0.0000	0.0695
1993	0.0000	0.0629
1994	0.0000	0.5782
3-Year Average	0.0000	0.2369

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Canvas Band Data**
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VII. VARIANCE COMPONENTS OF CANVAS BAND DATA

CARABIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	4.1870
1993	0.1397	1.5106
1994	0.1182	1.1803
3-Year Average	0.0860	2.2926

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	4.3313
1993	0.2850	1.5106
1994	0.2364	1.1803
3-Year Average	0.1738	2.3408

ELATERIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	6.4288
1993	0.0000	5.1640
1994	0.0000	4.6993
3-Year Average	0.0000	5.4307

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	6.6506
1993	0.2528	5.1677
1994	0.1740	4.7413
3-Year Average	0.1422	5.5199

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Canvas Band Data**
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FORMICIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0538	6.9728
1993	0.0000	7.1801
1994	0.5871	5.6069
3-Year Average	0.2136	6.5866

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.4286	6.9729
1993	0.2574	7.2505
1994	1.1610	5.6069
3-Year Average	0.6156	6.6101

AGELENIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.2259	5.1476
1993	0.1794	3.4683
1994	0.0311	2.4084
3-Year Average	0.1455	3.6748

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.5962	5.1476
1993	0.4425	3.4683
1994	0.1671	2.4084
3-Year Average	0.4019	3.6748

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Canvas Band Data**

GRYLLACRIDIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.2961	5.5751
1993	0.9124	5.0539
1994	0.8017	5.6152
3-Year Average	0.6701	5.4147

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.7229	5.5751
1993	1.6213	5.0539
1994	1.4833	5.6152
3-Year Average	1.2758	5.4147

ARTHROPOD ABUNDANCE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	0.0937
1993	0.0010	0.0303
1994	0.0022	0.0253
3-Year Average	0.0010	0.0498

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	0.0969
1993	0.0030	0.0303
1994	0.0045	0.0253
3-Year Average	0.0025	0.0508

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Canvas Band Data**

ARTHROPOD RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0014	0.0293
1993	0.0132	0.0730
1994	0.0346	0.1095
3-Year Average	0.0164	0.0706

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0036	0.0293
1993	0.0235	0.0730
1994	0.0574	0.1095
3-Year Average	0.0282	0.0706

MACROLEPIDOPTERA RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	0.2358
1993	0.0335	0.1107
1994	0.0682	0.2036
3-Year Average	0.0339	0.1834

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	0.2439
1993	0.0558	0.1107
1994	0.1125	0.2036
3-Year Average	0.0561	0.1861

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Canvas Band Data**

MACROLEPIDOPTERA ABUNDANCE WITH GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	0.1610
1993	0.0000	0.2532
1994	0.0008	0.1323
3-Year Average	0.0003	0.1822

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	0.1665
1993	0.0072	0.2570
1994	0.0078	0.1323
3-Year Average	0.0050	0.1853

MACROLEPIDOPTERA ABUNDANCE WITHOUT GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0000	5.2712
1993	0.0000	3.9656
1994	0.0652	0.8116
3-Year Average	0.0217	3.3495

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Bands
1992	0.0364	5.4281
1993	0.0533	4.0656
1994	0.1384	0.8116
3-Year Average	0.0760	3.4351

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Pitfall Trap Data**
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VIII. VARIANCE COMPONENTS OF PITFALL TRAP DATA

CARABIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.2082	0.1067
1993	0.1849	0.1188
1994	0.1855	0.1283
3-Year Average	0.1928	0.1179

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.3182	0.1067
1993	0.2839	0.1188
1994	0.2854	0.1283
3-Year Average	0.2958	0.1179

FORMICIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.3304	0.1963
1993	0.1151	0.1978
1994	0.1154	0.1667
3-Year Average	0.1870	0.1869

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.5065	0.1963
1993	0.1836	0.1978
1994	0.1824	0.1667
3-Year Average	0.2908	0.1869

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Pitfall Trap Data**

LYCOSIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.1433	0.0902
1993	0.0925	0.0795
1994	0.0418	0.1175
3-Year Average	0.0926	0.0958

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.2200	0.0902
1993	0.1432	0.0795
1994	0.0693	0.1175
3-Year Average	0.1442	0.0958

ARTHROPOD ABUNDANCE

Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.1409	0.0565
1993	0.0424	0.0505
1994	0.0656	0.0504
3-Year Average	0.0830	0.0524

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Site	Variation of Traps
1992	0.2146	0.0565
1993	0.0664	0.0505
1994	0.1011	0.0504
3-Year Average	0.1274	0.0524

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Light Trap Data**
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IX. VARIANCE COMPONENTS OF LIGHT TRAP DATA

Itame pustularia

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0000	0.4510
1993	0.0004	0.1732
1994	0.0000	0.1801
3-Year Average	0.0001	0.2681

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0000	0.5074
1993	0.0295	0.1732
1994	0.0000	0.2027
3-Year Average	0.0098	0.2944

Malacosoma americanum

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0000	4.6009
1993	0.0000	0.8631
1994	0.0000	0.3040
3-Year Average	0.0000	1.9227

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0000	5.1761
1993	0.0000	0.9709
1994	0.0000	0.3421
3-Year Average	0.0000	2.1630



**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Light Trap Data**

Halysidota tessellaris

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.3709	0.1453
1993	0.0000	0.0771
1994	0.0118	0.1404
3-Year Average	0.1275	0.1209

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.5805	0.1453
1993	0.0000	0.0867
1994	0.0410	0.1404
3-Year Average	0.2072	0.1241

Acronicta ovata

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.1815	0.1360
1993	0.0176	0.3022
1994	0.0056	0.2245
3-Year Average	0.0682	0.2209

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.2949	0.1360
1993	0.0768	0.3022
1994	0.0458	0.2245
3-Year Average	0.1392	0.2209

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Light Trap Data**

Lymantria dispar

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.2115	0.3007
1993	0.2954	0.7178
1994	0.0000	0.3164
3-Year Average	0.1690	0.4450

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.3674	0.3007
1993	0.5628	0.7178
1994	0.0000	0.3560
3-Year Average	0.3100	0.4581

MACROLEPIDOPTERA RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0117	0.0030
1993	0.0000	0.0197
1994	0.0000	0.0187
3-Year Average	0.0039	0.0138

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0181	0.0030
1993	0.0017	0.0209
1994	0.0000	0.0210
3-Year Average	0.0066	0.0150

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Light Trap Data**

MACROLEPIDOPTERA ABUNDANCE WITH GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0276	0.0356
1993	0.0007	0.1186
1994	0.0000	0.1424
3-Year Average	0.0094	0.0989

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0474	0.0356
1993	0.0208	0.1186
1994	0.0000	0.1602
3-Year Average	0.0227	0.1048

MACROLEPIDOPTERA ABUNDANCE WITHOUT GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0286	0.0354
1993	0.0006	0.1184
1994	0.0000	0.1426
3-Year Average	0.0097	0.0988

Restricted Maximum Likelihood Estimates of Components of Variance

	Variance of Block	Variance of Traps
1992	0.0487	0.0354
1993	0.0207	0.1184
1994	0.0000	0.1604
3-Year Average	0.0231	0.1048

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Malaise Trap Data**
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X. VARIANCE COMPONENTS OF MALAISE TRAP DATA

ELATERIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	3.5325
1993	0.0039	0.1529
1994	0.0121	0.1654
3-Year Average	0.0053	1.2836

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.4359	3.6471
1993	0.0313	0.1529
1994	0.0457	0.1654
3-Year Average	0.1709	1.3218

TACHINIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.2096
1993	0.0866	0.0779
1994	0.0000	0.1950
3-Year Average	0.0289	0.1609

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.2358
1993	0.1429	0.0779
1994	0.0000	0.2194
3-Year Average	0.0476	0.1777

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Malaise Trap Data**

ICHNEUMONIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0179	0.3355
1993	0.1815	0.0558
1994	0.0000	0.2874
3-Year Average	0.0665	0.2262

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0828	0.3355
1993	0.2815	0.0558
1994	0.0000	0.3233
3-Year Average	0.1214	0.2382

GELECHIIDAE

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0266	0.5119
1993	0.0243	0.0502
1994	0.0145	0.1858
3-Year Average	0.0218	0.2493

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.1252	0.5119
1993	0.0448	0.0502
1994	0.0527	0.1858
3-Year Average	0.0742	0.2493

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Malaise Trap Data**

ARTHROPOD RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.0346
1993	0.0030	0.0068
1994	0.0000	0.0047
3-Year Average	0.0010	0.0154

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.0389
1993	0.0057	0.0068
1994	0.0000	0.0053
3-Year Average	0.0019	0.0170

ARTHROPOD ABUNDANCE

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.2307
1993	0.0285	0.0131
1994	0.0000	0.1009
3-Year Average	0.0095	0.1149

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.2595
1993	0.0449	0.0131
1994	0.0033	0.1110
3-Year Average	0.0160	0.1279

**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Malaise Trap Data**

MACROLEPIDOPTERA RICHNESS

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.1002
1993	0.0000	0.0113
1994	0.0000	0.0178
3-Year Average	0.0000	0.0431

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0070	0.1074
1993	0.0000	0.0127
1994	0.0000	0.0200
3-Year Average	0.0023	0.0467

MACROLEPIDOPTERA ABUNDANCE WITH GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.1088	0.1756
1993	0.0000	0.0730
1994	0.0000	0.0914
3-Year Average	0.0363	0.1133

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.1924	0.1756
1993	0.0000	0.0822
1994	0.0000	0.1028
3-Year Average	0.0641	0.1202

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**Variance Components Of Five Sampling Methods For Detecting
 Population Changes Of Non-Target Arthropods
 Malaise Trap Data**
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MACROLEPIDOPTERA ABUNDANCE WITHOUT GYPSY MOTH

Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.1426
1993	0.0000	0.1426
1994	0.0000	0.1426
3-Year Average	0.0000	0.1426

Restricted Maximum Likelihood Estimates of Components of Variance

	Variation of Blocks	Variation of Traps
1992	0.0000	0.1604
1993	0.0000	0.1604
1994	0.0000	0.1604
3-Year Average	0.0000	0.1604

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**Variance Components Of Five Sampling Methods For Detecting
Population Changes Of Non-Target Arthropods
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XI. LITERATURE CITED

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