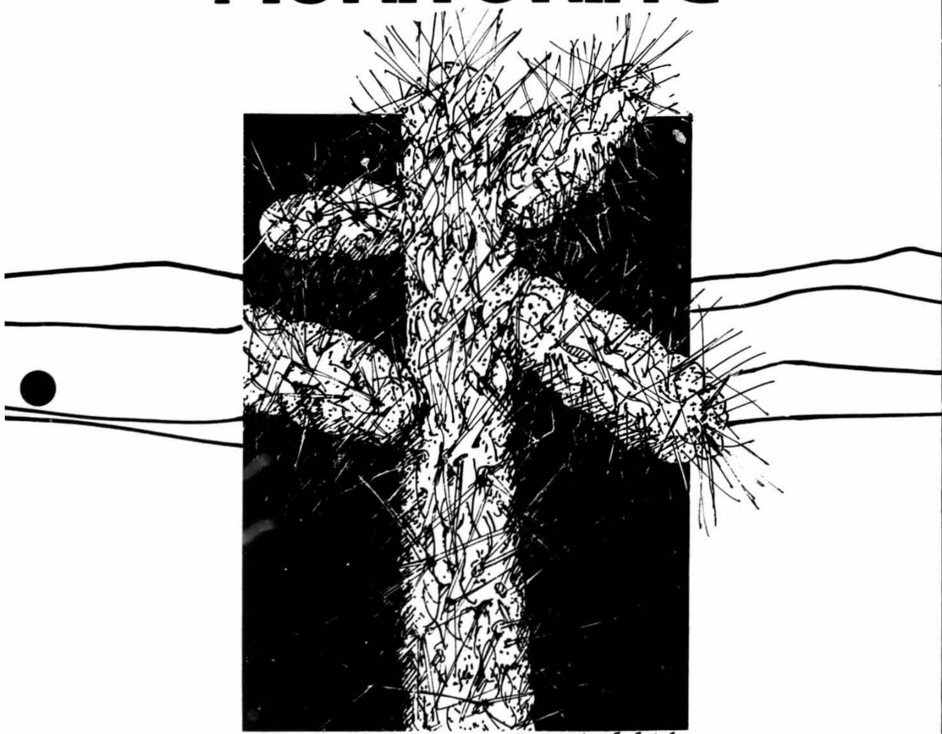
1992

Statistical Considerations in Rangeland Monitoring

United States Bureau of Land Management

RANGELAND MONITORING



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Statistical Considerations

TR 4400-8

1992

United States Department of the Interior
Bureau of Land Management

Statistical Considerations in Rangeland Monitoring

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Technical Reference 4400-8
September 1992

BLM/SC/PT-92/010+4400

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Preface

The information presented in this Technical Reference should be used in planning, analyzing, interpreting, and evaluating rangeland monitoring studies.

There are important statistical considerations that must be borne in mind when planning and conducting monitoring studies of BLM rangelands. The recommendations resulting from these studies must be defensible both academically and legally. This requires a substantial background in the principles and procedures of statistical inference.

Statistics is usually not the forte of the average BLM range conservationist, nor is it a subject matter that can be easily learned. There exists the feeling that all that is required is a few statistical formulas or a simple cookbook approach to assign meaning to data that were collected without regard for the type of data analysis to be performed. This feeling has been fostered in the Bureau by the frequent reference to "standard statistical procedures." There has to be some understanding the statistical methods, and usually this is not the case when data are collected more or less arbitrarily and the conclusions "validated" statistically.

Unfortunately, an average BLM range conservationist cannot become an accomplished statistician overnight, any more than a statistician can become an expert range conservationist by spending a couple of days in a BLM district. Understanding statistics takes time and effort, and there is no way around it. Once the statistical principles underlying the planning and conduct of monitoring activities are understood, the specifics of monitoring design and analysis can be easily determined; however, trying to implement specifics without knowing the fundamentals easily leads to false conclusions and decisions that cannot be defended.

The material that follows has been prepared to help BLM range conservationists cope with the statistical problems present in rangeland monitoring. The material is divided into five sections. Section 1 highlights the statistical topics required to analyze monitoring data and gives appropriate references. Section 2 addresses the underlying statistical issues of rangeland monitoring. Sections 3 and 4 deal with the specific methods used for trend and utilization studies. Section 5 shows examples of data analysis.

1. General Statistical Background

This section does not address statistics in detail. Instead, the statistical topics required to analyze rangeland monitoring data are mentioned and references are given for the study of the individual statistical concepts and techniques. There is a large selection of introductory books used by universities in their range conservation curriculum to which the BLM range conservationist can refer for clarification of specific concepts.

Characterization of vegetation data does not differ from the characterization of any other kind of data. Descriptive **measures of location and variation** are required. Measures of location are the mean, median, and mode. Measures of variation or dispersion are the range, the variance, and the standard deviation.

Inferences from the data collected are the main concern of statistical analysis. The purpose of **statistical inference** is to draw conclusions about **populations**. A population is a collection of things that have some common observable characteristics and about which we want information. We can have populations of trees, plants, the weights of plants, and the ground cover produced by particular plants.

In most cases, we cannot examine each element of the population and must be content with investigating only a part of the whole population. The part investigated is called a **sample**. A sample is a portion or subset of a population that is used to represent the population from which it is drawn. There are two types of samples: **statistical samples and judgement samples**. A statistical sample is one that is selected by a specific method of random selection. A judgement sample is one that is picked from the target population based on the subjective decision of an individual. Statistical samples can provide an objective measurement of the population characteristics; judgement samples cannot.

Sampling is done to draw inferences about the population sampled. The precision of inferences based on random samples can be assessed by means of **probability theory**.

Several **probability distributions** are used for describing vegetation characteristics. Most statistical analyses are based on the normal distribution. Other commonly used distributions used in the analysis of vegetation data are the Poisson, binomial and log normal.

Statistical analyses rest on the **connection between sampling and inference**. A statistic is a number computed from a sample. On the basis of the sample statistics, we make inferences about population parameters, which are numbers describing the content of the population under investigation. The most important fact to be used in statistical inference is that the distribution of sample means can be approximated by a normal distribution, and that the mean of this sampling distribution is the mean of the population. This is called the "central limit theorem".

A **sample statistic** estimates the value of the **population parameter**. The precision of such an estimate is measured by a quantity called the standard error, and this quantity is used to construct a **confidence interval** that we can be reasonably confident surrounds the unknown value of the population parameter. Confidence intervals for the population mean are easily estimated using the central limit theorem.

To compare two or more populations, we use **tests of significance**. A t-test is used to compare two sample means. Analysis of Variance (ANOVA) is used for comparing more than two sample means. Tests of significance involve the formulation of what is called a null hypothesis, an alternative hypothesis, and a level of significance. The level of significance gives the probability of rejecting the null hypothesis, when such a hypothesis is true. If we falsely reject the null hypothesis, then we are said to make a **Type I error**. Sometimes it is possible to accept a null hypothesis falsely, rather than reject it. In doing so we make a **Type II error**. Balancing the two types of errors is very important in rangeland monitoring.

All the above topics should be reviewed prior to continuing with Chapters 2 and 3 of this Technical Reference. Every range conservationist in the BLM has probably had at least one course in statistics during his/her college days. The textbook you used for such course should be a good reference. We recommend that you spend as much time as possible reviewing your old textbook. If your textbook is no longer part of your personal library, the following references are recommended:

Elementary statistics: Glantz (1987); Huntsberger and Billingley (1987); Mattson (1986).

More advanced statistics: Snedecor and Cochran (1980); Sokal and Rohlf (1981); Steel and Torrie (1980); Zar (1984).

Elementary sampling theory: Scheaffer, Mendenhall, and Ott (1986); Williams (1978).

More advanced sampling theory: Cochran (1977).

Experimental design: Box, Hunter, and Hunter (1978); Winer (1971).

All of the statistical procedures discussed and recommended in this Technical Reference (except for Chi-square analysis) are **parametric**; that is, they estimate population parameters (for example, means and variances) and test hypotheses concerning them. There are certain underlying assumptions that must be met or at least approximated in order for parametric statistical techniques to be valid. Chief among these is an underlying normal distribution and equality of variances.

There is another set of statistical procedures available that do not require assumptions regarding distribution and variance. (They do, however, still require random sampling.) These procedures are termed **nonparametric**, or distribution-free, statistics. All of the parametric techniques described in this technical reference have nonparametric analogues. Many statisticians believe that, in general, parametric techniques are more powerful than nonparametric techniques, as long as the assumptions required to use parametric statistics are reasonably well met. If in doubt about these assumptions, nonparametric methods can be used. Except for Chi-square analysis, which is a nonparametric technique, this Technical Reference does not discuss nonparametric methods. A considerable body of literature is available on this subject. Most of the statistics textbooks listed above discuss nonparametric statistics. In addition to these, the following books are valuable: Conover (1980); Lehmann (1975); and Sprent (1989).

2. Monitoring of BLM Rangelands

The BLM has several Technical References that deal with rangeland monitoring. (U.S. Department of the Interior, Bureau of Land Management, 1984a and 1985b). Technical Reference 4400-1, *Planning for Monitoring*, addresses the issue of sampling and sampling designs. Technical Reference 4400-7, *Analysis, Interpretation and Evaluation*, provides guidelines for data analysis. Both technical references give some general statistical guidelines.

Additionally, there are several well-known books on vegetation analysis and measurement techniques: Pieper (1978); Bonham (1989); Mueller-Dombois and Ellenberg (1974); Causton (1988); Krebs (1989); and Greig-Smith (1983). These books can help when planning a monitoring program.

At the planning stage of a monitoring program, the questions to be answered, the hypotheses to be tested, and the effects to be estimated should be stated clearly. All this should be examined systematically. Clearly, there is no cookbook approach that can be followed, but there are general guidelines.

2.1 What are the objectives?

The objectives should be stated clearly and precisely. Management objectives may be general, but the objectives of a sampling survey should be as specific as possible, each objective being stated as a hypothesis to be tested, a confidence interval to be computed, and a decision to be made. For example, the management objective may be to increase the percent cover of wheat grass from 10 to 15 percent in the Cranky Caribou key area. The objectives of the survey may be to estimate the percent cover with a margin of error of 2%, a 90% confidence interval, and within certain personnel and budget constraints.

2.2 What is sampled?

The target population from which the sample is to be drawn and for which inferences are to be made must be defined. To define the target population, one must specify:

a. The individual elements that make up the population.

b. The attribute of interest.

c. The way in which the attribute will be measured.

As an example, suppose that one wants to estimate the percent cover on the Cranky Caribou key area. Several questions may be asked:

a. Should any of the following areas be excluded?
   - riparian area
   - areas with slopes of 3% or more
   - areas within 50 yards of established roads

b. What sort of cover is desired?
   - basal
   - canopy
   - ground cover, including rocks and litter

c. How will the cover be measured?
   - line-intercept method
   - Daubenmire method

Using the above example, the target population might be the basal area of all plants on the Cranky Caribou key area, as determined by the Daubenmire method on slopes of less than 3%.

Next, the population must be divided into distinct sampling units which together constitute the population. Defining the sampling unit will answer the following questions:

a. How will the individual units of the population be grouped together for sampling purposes?
   - individually (i.e., not grouped)
   - by plots or transects
   - by groups of plots or transects

b. If by plots, what size and shape will be used?

c. If by transects, how long will they be?

Usually, the target population is individual plants, while the sampling unit is groups of plants, as defined by either transects or plots. Plots may be obtained by superimposing grids on maps of fields, forests, or other land areas.

2.3 How is the sample drawn?

The way in which samples are drawn is termed the sample design. There are several sample designs which may be appropriate for monitoring: simple random sampling, stratified sampling, and cluster sampling. The particular sampling design to be chosen is dictated by the nature of the problem and the availability of funds.

The recommended approach for selecting monitoring sites is to randomly select sites in areas with similar management activities. Randomly allocating sampling units eliminates any possible bias on the part of the range conservationist, thereby increasing the accuracy of the analysis. The purpose of randomization is to guarantee the validity of the test of significance, based on the estimate of error made possible by repeated sampling. The number of samples and the sample design required for a given monitoring project depend mostly on the degree of precision desired. For a given sample design, the smaller the effect to be detected, the greater the number of samples needed.

Some consideration should be given to the question of interspersion when selecting monitoring sites. Interspersion refers to the distribution in space of the sampling units and is important for minimizing bias and the possibility of spurious effects. Randomization alone does guarantee some degree of interspersion, but it may not be enough. If the randomized layout appears segregated, the simplest and most widely used solution is to reject it and "re-randomize" until a layout with an acceptable degree of interspersion is obtained. The importance of interspersion and its apparent contradiction to randomization are described in detail in Hurlbert (1984). As an aside, Hurlbert's paper could be interpreted as justification for systematic sampling, at least in the sense that such sampling helps insure that the quadrants, plots, or plants measured are in interspaced throughout the sampling area. Prince (1986) offers some interesting insight on the issue of random versus systematic sampling of vegetation, noting that systematic sampling may be more accurate than a simple random sample of the same size because of the often strong correlation that exists between neighboring measurements in the natural environment.

The method for data collection in the field is outlined in Technical Reference 4400-3 and Technical Reference 4400-4, (U.S. Department of the Interior, Bureau of Land Management, 1984c and 1985a). As emphasized by Hunter (1980), high quality data can be obtained only if dependable measuring techniques are used and if trained, experienced, and reliable field personnel are employed to collect the data.

For purposes of statistical analysis, it is preferable to randomly locate the plots or transects the first year and then measure the same plots or transects in succeeding years. Each plot or transect measured the first year is paired with the same plot or transect measured in subsequent years. The data can be compared using a paired t-test for two years' data and a repeated measures analysis of variance for three or more years' data. Since the members of each pair of plots or transects are positively correlated, there is an increase in the ability of the statistical procedure to detect a small difference. This is because the paired t-test and the repeated measures analysis of variance procedures eliminate a major source of variance, that existing from pair to pair. Instead of calculating the variance of differences among the individuals within each sample, the variance of the **differences** between the pairs is calculated. Steel and Torrie (1980, pages 102-105) and the other statistics texts referenced in Section 1 elaborate on the advantages of using paired observations.

2.4 Where are the samples taken?

The field sample selection procedure is potentially the largest single source of (selection) bias. Samples selected because they are "convenient" or "representative" may save effort in some cases, but they may also produce seriously biased results.

Random selection of sampling units can be easily accomplished. Let us illustrate this with an example. Suppose that we have determined that, for a given study, we need to select five transect locations in a key area. We proceed as follows:

- Get a map of the key area.
- Draw a grid directly on the map, or lay a grid over it.
- Number all the grid squares from one to N.
- Using a table of random numbers, or a random number generator on a computer or calculator, select five random numbers between one and N. This selects five locations on the map.
- Check the spatial arrangement for interspersion. If not satisfactory, continue drawing sets of five random numbers until a satisfactory spatial arrangement is reached.

The five transect locations are now selected. Next, determine the method to locate the transect within the site. One could decide, for example, to proceed to the southwest corner of the site and walk northwest until a suitable transect location is reached.

The size grid employed depends on:

a. How accurately a spot on the map can be located on the ground. There is no point in having a grid with 3,000 points if, in the field, only perhaps 300 points can be discerned.

b. The number of potential sample (transect) sites. If there are only, say, 100 potential sites, it makes no sense to have more than that number of grid points.

Another method that can be employed to locate random coordinates in the field is described by Awbrey (1977).

Yet another method of randomly locating transects is given in Technical Reference 4400-4 (U.S. Department of the Interior, Bureau of Land Management, 1985a), pages 31 and 32, and Illustration 24, page 101. This method involves permanently locating a 100-foot baseline by means of two stakes. Transects are then run perpendicular to the baseline at randomly selected points along a 100-foot tape. The direction of the transect (to the right or left of the baseline) is also determined randomly. Although the Technical Reference does not discuss it, care should be taken to run the baseline to minimize the amount of variability from one end to the other. If, for example, the area to be sampled is a hillside, and the vegetation changes as one goes up or down the slope, the baseline should follow a contour line. The transects will then **cross** the variability. The result will be that the transects will have the maximum amount of variability **within** them and the minimum amount of variability **between** them. This will make detection of differences more likely.

What is probably not well understood concerning the use of the 100-foot baseline technique is that the target population consists **only** of those plants within an area that is 100 feet by 2 times the length of each transect. For example, if each transect is 100 feet long, the target population is those plants within the 100-by-200-foot area that is potentially sampled by randomly placed transects. It is only for this area that statistical inferences can be made. Any inferences about the entire key area (assuming the key area is larger than 100 by 200 feet) are logical inferences rather than statistical ones.

The number of points in a transect and the distance between points is an important consideration. Longer transects may show less variation than shorter ones, unless they cross vegetation types, in which case they will show more variation than shorter ones. An increase in the size of the transect often results in a decrease in the number of replications that can be run, due to time and money constraints. Adequate replication of small transects is easier than adequate replication of large transects. It is usually more efficient to record more transects with fewer points per transect than fewer transects and more points per transect.

The key areas sampled should be as homogeneous as possible if simple random sampling is used. Where key areas contain more than one vegetation type, stratified sampling should be used to reduce the total variance. If transects are the sampling units, they should cross the variability in the vegetation. Each sampling unit should have as much variability within it as possible and the variation between sampling units should be kept to a minimum.

2.5 How large a sample should be taken?

The size of the sample required to detect differences depends on the following three items:

a. The natural variability in the population.

b. The precision required.

c. The acceptable risk in the determination of confidence intervals.

Large within-site variability requires more sampling units (unless one uses paired plots or transects—see discussion under 2.3 above). Often, some source of variation (such as elevation or aspect) can be identified and the variation in the sampled variable can be at least partially explained. One can generally control the magnitude of this explained portion of the variation. The remaining unexplained variability will dictate the number of sampling units to take.

The desired degree of precision indicates how close to the true mean the sample mean should be. Precision can be increased by increasing the sample size and by carefully selecting the sampling unit and sample design.

The level of significance at which the null hypothesis is going to be tested determines the width of the confidence intervals. The level of significance is a specification of the acceptable risk that the actual confidence interval does not cover the true mean. The lower the risk tolerated, the larger the sample size.

Setting the precision and confidence limits requires knowing the importance of the information being obtained and the resources available to do the necessary sampling and measurement. Some general guidelines are:

a. Use 10% precision and 75% or 80% confidence when testing controversial hypotheses (i.e , when a future court appearance seems likely).

b. Use 20% precision and 80% confidence for general resource management.

The recommendation for a 75% or 80% level of significance versus the more conventional 90% or 95% level is based on the need to lower the chances of committing a Type II error. Whenever we have controversy in the BLM we usually have resource deterioration. Therefore, we want to lower the chances of accepting the null hypothesis of no change in resource condition (Type II error) when in fact the resource has deteriorated. The RISC (Range Inventory Standardization Committee) report recommends 80% as a reasonable confidence level.

In summary, higher confidence, higher precision, and greater variability all dictate increased sample sizes. When an insufficient sample size is used, a significant difference may exist but not be apparent. Conclusions drawn from such an analysis may, therefore, be invalid.

Technical References 4400-3 and 4400-4 (U.S. Department of the Interior, Bureau of Land Management, 1984c and 1985a), often recommend specific sample sizes. The sizes given in

those documents should be compared to the sample sizes determined to be necessary using the considerations discussed above for the particular level of significance, degree of precision, and variability in the target population. All of these factors are combined in formulas for sample size determination (for example, Sokal and Rohlf 1981, pages 262-264).

An alternative to using formulas to determine sample size is to make use of sequential sampling techniques, whereby sampling continues until additional plots or transects do not significantly affect the mean (for the attribute of interest) of the more important (or abundant) plants. This technique is described by Mueller-Dombois and Ellenberg (1974, pages 77-80).

2.6 What statistical tests should be used?

Most range monitoring information is analyzed using Chi-square, confidence limits, t-test, Analysis of Variance (ANOVA), and time series regression analysis. The type of analysis selected depends upon (1) the number of plots or transects sampled, (2) the number of years of data, and (3) the type of data collected (cover, frequency, density).

The two essential requirements of these tests are that (1) sampling must be random and (2) the sampling units (transects or plots) must be independent. Additional assumptions for ANOVA are (3) an underlying normal distribution and (4) equal variability within subgroups. Although plant attribute data and percent data usually violate requirement (3), data transformation can be used to approximate a normal distribution and lack of normality can be easily mitigated. In general, lack of normality and inequality of subgroup variation tend to increase the overall variance, thus decreasing the chance of finding significant differences.

If requirements (1) and (2) are violated, no valid statistical analysis is possible. Statistical analysis is not possible with data that have been arbitrarily collected. Statistical analysis is not just something added at the end of the investigative process to validate a foregone conclusion or to dress up the results. On the other hand, if a sound sampling design has been used, the conclusions will have statistical validity and will be able to withstand outside scrutiny.

Three common analyses of range monitoring data are (1) determining confidence limits for a given year, (2) comparing two years, and (3) comparing three or more years.

1. Determining confidence limits for a species for a given year.
   - Statement you can make: "I am 90% confident that the percent cover of AGSP on the Cranky Caribou key area is between 13% and 21%"
   - Statistical test to use: Confidence limits on the year of interest.

2. Comparing two years for a single species.
   - Statement you can make: "The increase in AGSP from 10% to 17% in the Cranky Caribou key area from 1983 to 1987 was statistically significant at the 15% level."
   - Statistical test to use: t-test, paired if the same plots or transects were measured in the two years; two-sample if the same plots or transects were not remeasured.

3. Comparing three or more years for a single species.

   - Statement you can make: "There was a significant change in AGSP in the Cranky Caribou key area from 1975 to 1988," or "there was a significant increasing linear trend in AGSP in the Cranky Caribou key area from 1975 to 1988."
   - Statistical test(s) to use: If different plots were used each year, use analysis of variance and Duncan's test or other multiple comparisons tests (Day and Quinn, 1989) to determine which years are significantly different. The appropriate ANOVA model to use is that associated with a randomized complete block design, in which the treatments are the years and the blocks are the transects or plots (Winer, 1971). The analysis of variance can be used to detect linear and higher order trends.

If the same plots were re-measured in each year, the appropriate analysis of variance to use is that associated with a single-factor experiment having repeated measurements on the same elements. The treatments are the years, and a test for trend is used to detect a possible trend across the years (Winer, 1971).

Once a statistical method is chosen to test the hypothesis, stick with the method. An unexpected or undesired result is not by itself a valid reason for rejecting the method or the results. Examine all the steps involved in the analysis, beginning with the sampling design and the data collection phase. Scrutinize every aspect of the study. Then, make the decision whether to repeat the study or to use another sampling design and analysis.

2.7 How are the statistical analyses run?

All the statistical analyses required for rangeland monitoring can be run using existing computer packages, either on the Honeywell mainframe or on a PC.

The Honeywell mainframe in Denver has two general statistical packages and one specific rangeland monitoring program. The general statistical packages are STATPAK and SPSS. STATPAK can be accessed interactively and will suffice for t-tests, two-way analysis of variance, and linear regression. SPSS has to be accessed in a batch mode and it is a bit more cumbersome to use, but it is very comprehensive and is the best commercial package available. The specific rangeland monitoring package is called A121/RENO/MONITOR (1985) and uses ANOVA and Duncan's Multiple-Range Test to compare frequency and cover data across the years to detect any significant changes. The MONITOR program assumes a two-way randomized block design. The treatments are the years and the replications are the transects. The error term is the year x transect interaction. With the two-way randomized block design model, it is possible to identify significant differences between two or more years of data and two or more transects. In the instances when the number of transects is small and the two-way randomized block design model shows no significant difference between years and between transects, a completely random design model with a single criterion of classification is also available to investigate possible significant differences between years.

There are many PC statistical packages. Just about any one will do most of the analyses required for rangeland monitoring. SPSS is available in the PC version and is called SPSSPC+. It comes in two packages: a basic package and an advanced package. They have the same capabilities as the corresponding mainframe SPSS packages. Other packages are STATGRAPHICS, MINITAB, SAS, ISP, SYSTAT, and others.

2.8 Where and how should the information collected be stored?

Information obtained from the monitoring program should be assembled in a format that is understandable by both resource specialists and decision makers. Document the objective(s) of the experiment, the details of the design of the experiment, the data collection phase, and the data analysis phase.

The data collected should be entered into a data file or data base that is compatible with the statistical package used for the analysis. If the data are stored in a data base, updating and retrieval are considerably easier. Data base managers such as ASPEN/2 or dBASE III are suggested for data storage. ASPEN/2 is available on both the Honeywell mainframe and PCs, while dBASE III Plus is available on PCs. Since the data have to be entered into a computer for analysis, it makes sense to store the data in a data base format from which it can always be recalled for analysis or for further retrieval and update.

3. Analysis of Trend Study Methods

The various trend study methods discussed in Technical Reference 4400-4 (U.S. Department of the Interior, Bureau of Land Management, 1985a) can be aggregated into three groups for the purposes of data preparation and data analysis. All of the methods discussed in the Technical Reference are covered here. If your method is slightly different from those discussed in Technical Reference 4400-4, read the description of the methods covered by the three groups. Then select the closest group.

3.1 Methods for photo plot, line intercept, and step point.

This group includes the following methods from TR-4400-4:

Method	Section	Pages	Data Collection Form Illustration	Data Collection Form Pages
Photo Plot	4.41	6-11	6	70-73
Line Intercept	4.47	42-45	30	112-113
Step Point	4.48	46-50	31	114-115

Each plot or transect measured produces only one estimate of the percent cover, density, etc., for each species. The same plots or transects may or may not be remeasured in subsequent years. Plots may be of different sizes and transects may have different lengths from year to year.

Obviously, if only one plot or transect per key area is established, the data obtained cannot be statistically analyzed. Several plots or transects (preferably 10 or more) are necessary for statistical analysis. In general, several shorter transects are better than one longer transect. Four 50-point transects will provide more information than one 200-point transect.

The statistical analysis to be recommended is based on the following assumptions: (a) the plots or transects are randomly placed and (b) the transects are independent, while the plants or plots within transects are not independent. In addition, if the same plots are sampled every time, this has a bearing on the type of analysis used.

3.1.1 Cover data preparation.

a. Photo plot and line intercept methods.

For each plot, use the percent cover computed on the data collection forms given in TR-4400-4.

b. Step point method.

Compute the percent cover for each transect for each species or cover category at each level (ground or basal and foliar, levels 1, 2, and 3). As an example, let us use the data on page 115 of TR-4400-4 (U.S. Department of the Interior, Bureau of Land Management, 1985a) and work through the computations for ground and foliar 1 levels. This transect has only 100 points rather than the 200 specified by the method, but the 100 points will make computations easier.

All 100 points have to hit something on each level, even if that something is "thin air." Thus the total hits for each cover layer must total 100. For the layers in which the count does not add up to 100, one can assume that the missing values are the "thin air" hits. In the page 115 example, 39 of the 100 points hit ground level without hitting anything above that layer, while 61 of the points hit some form of vegetation. To compute the percent cover at the ground level, combine the ground-level category cover with the basal or ground-level category from the basal and foliar cover as follows:

category	number of hits	percent cover
B	16	16
P	5	5
N	23	23
G	21	21
C	6	6
S	2	2
R	0	0
BOGR2	22	22
SIHY	2	2
BOCU	2	2
OPUNT	1	1
Total	**100**	**100**

Compute the percent cover for the foliar - level 1 as follows:

category	number of hits	percent cover
BOCU	20	20
BOGR2	3	3
JUNIP	20	20
ERIOG	2	2
SIHY	2	2
VIQUI	2	2
N	4	4
BOHI2	3	3
P	2	2
"Thin Air"	42	42
Total	**100**	**100**

Remember, there are 100 points and all of them must be accounted for. Therefore, those which are not listed on the data collection forms are the "thin air" hits.

3.1.2 Density data preparation.

Compute the density by dividing the number of plants of each species by the square footage of the plot, i.e., 9 for a 3' x 3' plot and 25 for a 5' x 5' plot. Using the data on page 73 of TR-4400-4, the conversion to plants per square foot would be as follows for the listed species:

Species	Number of plants	Plants per square foot
AGSP	4	4/9 = 0.44
POSE	28	28/9 = 3.11
SIHY	2	2/9 = 0.22
FIED	4	4/9 = 0.44

3.1.3 Cover data file creation. [1]

Make separate data files for each species for each cover category you wish to compare. Note that cover category only applies to the Step Point Transect method, where more than one sort of cover data are collected. If only one cover category was collected, then only one data file for each species is necessary. Make separate columns for each year and separate rows for each transect. So, assuming that there are five transects, and that you wish to compare three years, the data file would have five rows and three columns. The data file for BOCU, for foliar - level 1, might look something like this:

Transect	1984	1985	1986
1	20	15	35
2	24	14	6
3	19	0	5
4	5	13	14
5	10	10	20

3.1.4 Density data file creation.

Make separate data files for each species you wish to compare. Make separate columns for each year and separate rows for each plot. The data file would have the same number of rows and columns as the one for percent cover, with the only difference being that the file would have density values rather than the cover percentages.

3.1.5 Transformation of data.

Transformation of cover data is required to make the data approximately normally distributed. The recommended transformation is the arcsine square root, $\arcsin\sqrt{y}$, with the cover y expressed as a decimal fraction. Transformation of the density data is recommended since enumeration data often follows a Poisson distribution. Use the square root transformation.

[1] Different statistical packages may require different data file structures than the one shown in this technical reference.

3.1.6 Analysis of one transect or plot per year.

No statistical analyses are possible for either density and cover data.

3.1.7 Analysis of two or more transects per year.

a. Confidence intervals.

To estimate either the density or the percent cover for the key area in any given year, construct a confidence interval for the year of interest.

b. Comparing two years.

If the same plot locations were used in both years, use a paired t-test. If the same plot locations were not used in both years, then use a two sample t-test.

c. Comparing three or more years.

If the same plot locations were used in all years, the appropriate analysis is an ANOVA for a single factor experiment having repeated measurements on the same elements. If the same plot locations were not used in all years, then an ANOVA for a randomized complete block design is the appropriate analysis. The treatments are the years and the blocks are the transects or plots. Duncan's Multiple-Range Test can be used to detect individual differences between the years. The ANOVA can also detect linear and higher-order trends between years.

3.2 Procedures for community structure analysis and the Daubenmire method.

This group includes the following methods from TR-4400-4:

Procedure	Section	Pages	Data Collection Form Illustration	Data Collection Form Pages
Community Structure Analysis	4.42	12-17	10-13	77-82
Daubenmire Method	4.43	18-23	14-15	89-89

Measurement of a plot or transect involves tallying the data into different groups so that the final figures are counts by category of the information obtained from reading the transect. The same plots or transects may or may not be measured in subsequent years. For analysis purposes, plots or transects can be of different sizes or lengths from year to year.

The transects in these two methods should be permanently marked. However, for statistical analysis it will be assumed that new transects are established each year. This is because different people pace at different lengths, and the exact same spot of ground is not remeasured each year. Additional assumptions are that the transects are independent and randomly placed. The plots within the transects are usually not independent.

If only one transect per key area is established, no rigorous statistical analysis will be possible for either cover or frequency, since each transect produces only one data point for cover or frequency. As pointed out earlier, several shorter transects make more sense than a longer transect. Four randomly placed, independent, 25-pace transects are more meaningful than a single 100-pace transect, because the replications make possible the estimation of sampling error.

A questionable analysis for cover may be possible if only one transect per key area is established. A Chi-square analysis can be done to compare cover classes by years. The analysis will be suspect, however, because the data points along the transect were not collected in a truly random fashion and are probably not independent. Both of these conditions are required for a valid Chi-square test.

When density data are being collected using the Community Structure Analysis and only one transect has been established, it may be possible to use statistical analysis. If the circular density plots within the transect are spaced far apart, their degree of interaction may be minimal. In that case, a 10-plot transect can be considered to have 10 independent density values.

3.2.1 Cover data preparation.

a. One transect per year.

The numbers of counts per cover class will be used as input to the statistical analysis. The appropriate analysis is the computation of the chi-square statistic from a two-way contingency table. This analysis requires at least five or more counts in each category, so combine cover classes to obtain five or more counts per category per year. As an example, let us use the data for 1984 on page 78, TR 4400-4, and make up the data for 1986 and 1988. Let us say that, for some reason, we are only interested in species beginning with the letter A, which will include ASTRA and ATOB. Also, let us combine all cover classes over 25% into one category. The table produced from these categories would look like this:

Number of Counts by Cover classes for the "A" species.

Cover class	1984	1986	1988
1-5%	7	14	10
5-25%	14	22	18
25% and over	7	10	5

Similar tables can be prepared for each species combination and cover class combination of interest.

b. Two or more transects per year.

If more than one transect per key area has been established, the data file construction and analysis will be quite different. One cover value is computed for each transect as described on page 85, TR-4400-4. These cover percentages will be used as the basis for the analysis. It makes no difference whether cover was computed using the 6- or 10-cover class method.

3.2.2 Density data preparation.

First, convert the density count data to density per square foot (or square meter) by dividing each count by the size of the hoop used. For example, if a 9.6 square foot hoop is used, divide each count by 9.6 Converting the data allows comparison of data collected with different size hoops or plots. If species are combined, it makes no difference whether the species are added together before or after dividing by the area of the hoop or rectangle.

For each species, or combination of species, of interest, make a data file containing the density per unit area values. Make columns for each year and rows for each plot. As an example, the data for HIJA would be converted to density per square foot as follows:

Plot	count	density=count/9.6
1	4	.42
2	3	.31
3	0	.00
4	7	.73
5	2	.21
6	5	.56
7	7	.73
8	0	.00
9	2	.21
10	6	.63

The zero counts must be included. However, because the cell counts are too small, this species should be combined with other species until the cell counts are greater than or equal to 5. Do combine species, but do not combine the plots since each plot is an independent estimate of the total.

3.2.3 Frequency data preparation.

If only one transect per year was established, no statistical analysis is possible. When several transects per year are run, the frequency data must be collected with the same size plot each year in order to obtain valid comparisons between years.

3.2.4 Cover data file creation.

a. One transect per year.

Make separate data files for each combination of species and cover classes to be compared. Make separate columns for each year, and separate rows for each cover class or combined cover classes. The same cover classes must be used for all years being compared.

b. Two or more transects per year.

Make separate data files for each species or combination of species to be compared. Make separate columns for each year and separate rows for each transect. So, assuming that there are five transects and that one wishes to compare three years, the data file would have five rows and three columns. It might look something like this:

Transect	1984	1986	1988
1	33	40	55
2	24	54	66
3	30	50	25
4	55	33	44
5	10	30	20

The values in the table are the percent cover.

3.2.5 Density data file creation.

Make separate data files for each species or combination of species to be compared. If the density values computed for HIJA under the density data preparation section (TR-4400-4) are used for 1984, and contrived values are generated for 1986 and 1988, the data file could look like the following:

Plot	1984	1986	1988
1	.42	.40	.55
2	.31	.54	.66
3	.00	.50	.25
4	.73	.33	.44
5	.21	.30	.20
6	.56	.66	.45
7	.73	.43	.76
8	.00	.22	.43
9	.21	.00	.78
10	.63	.21	.00

3.2.6 Frequency data file creation.

As stated earlier, unless more than one transect per key area was measured, no statistical analysis is possible. If more than one transect was measured, the data file would be constructed with one column for each year and one row for each transect, the same as for cover with two or more transects per year. Each species must have a separate data file. If species are combined, new percent frequencies must be computed by combining the species on a plot-by-plot basis and then computing a frequency from those values.

3.2.7 Transformation of data.

No transformation of cover data is required if data on only one transect per year are available. Otherwise, cover data should be transformed using the arcsine square root transformation. Before applying the transformation, express the cover data as a decimal fraction.

Density data should be transformed using the square root transformation. Frequency data should be handled similarly to cover data. Use the arcsine square root transformation, expressing the frequency as a decimal fraction.

3.2.8 Analysis of one transect per year.

Two or more years of cover data can be compared using a two-way contingency table and the chi-square statistic.

Two years of density data can be compared using a t-test. Use a paired t-test if the same plots were measured. Otherwise, use a two-sample t-test.

If three or more years of density data are available, and if the same plots were remeasured, use ANOVA with repeated measurements. If the same plots were not remeasured, use a two-way analysis of variance in which the treatments are the years and the blocks are the plots. Duncan's Multiple-Range Test can be used to determine which years are different.

No frequency comparisons are possible with only one transect per year.

3.2.9 Analysis of two or more transects per year.

a. Confidence intervals.

To estimate the cover, density, or frequency for the key area in any given year, construct a confidence interval for the year of interest.

b. Comparing two years.

Cover and frequency data can be compared using a t-test. Use a paired t-test if the same plots were measured. Otherwise, use a two-sample t-test.

To compare density data, either use a t-test, if comparing transects, or an ANOVA, if the transects are subdivided into plots. The analysis of variance model is a randomized block design with more than one observation per block. The treatments are the years. The blocks are the transects. The repeated observations are the plots within the transects.

c. Comparing three or more years.

Cover and frequency data are analyzed using a two-way ANOVA for a randomized block design. The years are the treatments and the transects are the blocks. Duncan's Multiple-Range Test can be used to detect differences between the years. The ANOVA of variance can also detect linear and higher-order trends.

Density data can be analyzed two ways. If the plots within the transects are pooled, use the model recommended for cover and frequency. If the plots within the transects are treated as replicated measurements, use an ANOVA randomized block design with more than one observation per block. The treatments are the years, the blocks are the transects, and the repeated observations are the plots within the transects.

3.3 Methods for pace frequency, quadrat frequency, and nested frequency.

This group includes the following methods from TR-4400-4:

Method	Section	Pages	Data Collection Form Illustration	Data Collection Form Pages
Pace Frequency	4.44	24-28	18	93-94
Quadrat Frequency	4.45	29-35	12	97-98
Nested Frequency	4.46	36-41	25-28	102-109

The sampling unit in the three methods is the transect. The transects are randomly placed and are assumed to be independent. For the purpose of the statistical analysis, it is assumed that new transects are established each year, since it is practically impossible to remeasure the same transect and plots year after year. The plots within the transects are not independent. Precision can be increased by increasing the number of transects. Accuracy is increased by increasing the number of quadrants within transects.

3.3.1 Cover data preparation.

Compute the percent cover for each transect for each cover category, similar to what is done for the total of the four transects on page 94, TR-4400-4. For example, here are the conversions for the cover categories for transect 1, page 94 of TR 4400-4:

Cover category	count	% cover
Bare Ground	7	(7/50)x100 = 14
Persist. Litter	2	(2/50)x100 = 4
Non-Per. Litter	22	(22/50)x100 = 44
Rock	9	(9/50)x100 = 8
Live Veg.	10	(10/50)x100 = 20

Similar computations would be done for each transect for each cover category and each species.

3.3.2 Frequency data preparation.

Compute the frequency for each plot size for each transect for each species, similar to what is done for the total of the four transects on page 94 of TR-4400-4. For example, here are the conversions for the species for transect 1, page 94 of the reference.

Species	count	frequency
AGSP	25	(25/50)x100 = 50
KOCR	21	(21/50)x100 = 42
PONE3	40	(40/50)x100 = 80
STVI4	10	(10/50)x100 = 20
PHLO2	5	(5/50)x100 = 10
ASTER	8	(8/50)x100 = 16
PENST	1	(1/50)x100 = 2
GUSA2	3	(3/50)x100 = 6
CHNA2	0	(0/50)x100 = 0
ARTR2	7	(7/50)x100 = 14

Similar computations would be done for each transect for each cover category, each plot size, and each species.

3.3.3 Cover data file creation.

Make a separate data file for each cover category for which you wish to compare years. Make separate columns for each year and separate rows for each transect. So, assuming that there are four transects and that you wish to compare three years, the data file would have four rows and three columns. If the 1984 data for bare ground from page 94, in TR-4400-4, are used and we make up data for 1986 and 1988, the data file would look something like this:

Transect	1984	1986	1988
1	14	04	25
2	26	35	43
3	52	39	65
4	44	16	30

3.3.4 Frequency data file creation.

For nested frequency data, choose for each species the plot size that will keep the percent frequencies between 20 and 80 percent, if possible. Make a separate data file for each species and each plot size for which you wish to compare years. It will rarely be necessary to compare more than one plot size category for each species. For quadrat frequency, only one plot size is used, so a choice will not have to be made.

Make separate columns for each year and separate rows for each transect. Assuming that there are four transects and that you wish to compare three years, the data file would have four rows and three columns. If the 1984 data for AGSP for plot size 3 from page 105, in TR-4400-4, are used for 1984 and data are made up for 1986 and 1988, the data file would look something like this:

Transect	1984	1986	1988
1	36	50	52
2	34	35	43
3	40	39	65
4	52	16	30

3.3.5 Transformation of data.

Transformation of both frequency and cover data is required to make the data approximately normally distributed. The recommended transformation is the arcsine square root, arcsin y, with y expressed as a decimal fraction.

3.3.6 Analysis of two or more transects per year.

a. Confidence intervals.

For both cover and frequency, do confidence intervals for the years of interest.

b. Comparing two years.

For both cover and frequency, use a two-sample t-test. The number of plots may be different for the two years being compared.

c. Comparing three or more years.

Cover and frequency data are analyzed using a two-way analysis of variance model for a randomized block design. The treatments are the years and the transects are the blocks. Duncan's Multiple-Range Test can be used to detect differences between the years. The ANOVA can also detect linear and higher-order trends.

4. Analysis of Utilization Study Methods

This section addresses all of the utilization study methods described in Technical Reference 4400-3.

All utilization methods express utilization as a percentage of the current year's production that has been removed. Each plot or transect measured produces an estimate of the percent utilization for each species, and several plots or transects are required to estimate the sampling error.

The sampling unit in the paired plot method is the pair of plots. The difference between the protected and the unprotected plot represents the amount of forage consumed or destroyed during the foraging period. The protected and unprotected plots are dependent, but the pairs of plots are independent.

In all of the other methods, the sampling unit is the transect. The transects must be independent and randomly placed.

None of the utilization methods recommends that the same plots or transects be remeasured in subsequent years.

As expressed repeatedly in the range monitoring section, there can be no statistical analysis if only one plot or transect is measured per year. No estimate of the sampling error is possible unless several samples are collected. Hence, several shorter transects are more meaningful than one longer transect. A 50-point transect will provide more information if it is separated into five transects of 10 observations each.

4.1 Paired plot method data preparation.

Compute the percent utilization for each plot for each species. The data for AGSP from TR-4400-3, illustration 2, page 54, will be used as an example. Use the same formula as for the overall percent utilization, (P-U)*100/P, but compute percent utilization for each plot as follows:

PLOT 1 $\frac{P-U}{P} \times 100 = \frac{25-15}{25} \times 100 = \frac{10 \times 100}{25} = 40\%$

PLOT 2 $\frac{P-U}{P} \times 100 = \frac{40-25}{40} \times 100 = \frac{15 \times 100}{40} = 38\%$

PLOT 3 $\frac{P-U}{P} \times 100 = \frac{30-15}{38} \times 100 = \frac{23 \times 100}{38} = 61\%$

PLOT 4 $\frac{P-U}{P} \times 100 = \frac{30-18}{30} \times 100 = \frac{12 \times 100}{30} = 40\%$

PLOT 5 $\frac{P-U}{P} \times 100 = \frac{28-12}{28} \times 100 = \frac{16 \times 100}{28} = 57\%$

4.2 Data preparation in all the other methods.

Compute the percent utilization for each transect and for each species as it is done in TR-4400-3.

4.3 Data file creation for all methods. [2]

Make separate data files for each species you wish to compare. Make separate columns for each year and separate rows for each plot. Assuming that there are five plots or transects, and that you wish to compare three years, the data file would have five rows and three columns. It should look something like this:

Transect or Plot	1984	1986	1988
1	33	40	55
2	24	54	66
3	30	50	25
4	55	33	44
5	10	30	20

4.4 Transformation of data.

Use the arcsine square root transformation for all utilization data. Express utilizations as a decimal fraction.

4.5 Analysis.

a. Confidence intervals.

Do confidence intervals on the years of interest.

b. Comparing two years.

Use a two sample t-test. This is **not** a paired t-test. If the same plot locations were used in both 1984 and 1988, then it would be a paired t-test. However, this should not be done. See Technical Reference 4400-3, page 7, (b) Continuing Study, for a discussion of this. Note also that, since it is a two-sample t-test, the number of plots may be different for the two years being compared.

c. Compare three or more years.

Use a two-way ANOVA for a randomized block design. The years are the treatments and the transects or plots are the blocks. Duncan's Multiple- Range Test can be used to determine which years are different. The ANOVA can also detect linear and higher-order trends.

[2] Different statistical packages may require different data file structures than the one shown in this technical reference.

5. Examples of Data Analysis

What follows are example problems that are solved using SPSSX and STPK on the Honeywell mainframe. SPSSX is used in a batch mode. STPK is used interactively. Each example is solved using both SPSSX and STPK. For SPSSX, the command file with the list of SPSSX commands required to solve the problem is shown first. The computer solution follows. For STPK, the whole interactive session is shown.

The reason for showing both SPSSX and STPK is to show the reader that STPK, although a modest package compared to SPSSX, can accomplish most of the analyses required for rangeland monitoring. It does not have the capabilities to do Duncan's Multiple-Range Test or linear contrasts, but it can do all of the other tests. Duncan's can be done using A121/RENO/MONITOR and linear (and higher-order) contrasts can be easily done by hand, as will be shown.

SPSSX is a package that is geared to the statistician. Some may find it a bit too complex and may opt to use STPK or any of the other statistical packages available for the micro. By using STPK as a reference, you should be able to establish the suitability of other interactive statistical packages that you may have available on your PC.

5.1 Data sets used.

The following data sets are used in the examples that follow.

ONECDATA. Cover count for 3 cover classes and 3 years. Cover classes are rows, years are columns. Exhibit 1.

CHDATA. Cell entry counts by cover classes 1, 2, and 3, for years 84, 85, and 86. Exhibit 2.

XXDATA. Frequency counts for 10 transects for 5 years. Cell entries by year and transect. Exhibit 3.

YYDATA. Frequency counts for 10 transects for 5 years. Transects are rows, years are columns. Exhibit 4.

DDDATA. Density for 2 transects, 4 years, and 3 replications. Cell entries by transect, year, and replication. Exhibit 5.

5.2 Example of t-test.

SPSSX.

a. Independent Samples.

The SPSSX command file is shown in Exhibit 6. This command file selects the data from data set XXDATA, transforms the data using the arcsin transformation, and compares years 1 and 2 using a t-test for independent samples. The data are first divided by 20, since there are 20 quadrants per transect, to get decimal fractions. Then, the arcsin√ of the fraction is computed to obtain radians. The radians are converted to degrees by multiplying by $360/\pi = 57.29578$.

The SPSSX results are shown in Exhibit 7.

b. Paired Samples.

The SPSSX command file is shown in Exhibit 8. This command file selects the data from data set YYDATA, transforms the data using the arcsin√ transformation, and makes paired comparisons of year 1 and year 2 using a t-test for paired samples. The data transformation is the same as described in item a above.

The SPSSX results are shown in Exhibit 9.

STPK.

The interactive session is shown in Exhibit 10. It uses data set YYDATA, transforms the data using the arcsin transformation. and compares year 1 and year 2 for both independent samples and paired samples using the t-statistic. The results agree with the SPSSX results.

5.3 Example of Two-way ANOVA (Randomized block design).

SPSSX.

The SPSSX command file is shown in Exhibit 11. The command file uses data set XXDATA, transforms the data using the arcsin√ transformation, and performs a Two-way ANOVA using a randomized block design. The years are the treatments and the transects are the blocks. It also computes linear and higher-order contrasts to detect trends.

The SPSSX results are shown in Exhibit 12. The F value for YEAR indicates significant difference between the years at the 0.000 level of significance. The F value for the first PARAMETER under YEAR shows the significance of the linear trend at the 0.000 level of significance. Notice that the F values for the 2nd, 3rd, and 4th PARAMETER under YEAR (quadratic, cubic, and quartic trend components) are not significant at the 0.1 level.

STPK.

The interactive session is shown in Exhibit 13. It uses data set XXDATA, transforms the data using the arcsin√ transformation, and performs a Two-way ANOVA.

The linear and higher-order contrasts can be easily calculated by hand. We need to know the yearly totals for the transformed data and the contrast coefficients. The totals can be obtained by using the GROUP 1, TRANSFORMATION analysis option in the STPK menu, printing the data, and summing the totals for the years. The contrasts coefficients can be obtained from Winer (1971, p.878).

For the XXDATA, the transformed year totals are:

Year	1	2	3	4	5
	444.00	537.16	562.50	652.46	767.64

and the contrast coefficients, c, are:

						Σc^2
Linear	-2	-1	0	1	21	0
Quadratic	2	-1	-2	-1	2	14
Cubic	-1	2	0	-2	1	10
Quartic	1	-4	6	-4	1	70

Then, the linear contrast F can be computed (Winer, 1971, p.296):

$C_{lin} = (-2)(444.00)-(1)(537.16)+(1)(652.46)+(2)(767.64)$
$= 762.58$

$C_{lin} = 581528.26$

$MS_{lin} = C_{lin}/n\Sigma c^2 = 581528.26/((10)(10)) = 5815.2826$

$F_{lin} = MS_{lin}/MS_{residual} = 5815.2826/109.84$
$= 52.94$

which agrees with the F for the linear trend in the SPSSX printout.

Similarly for the quadratic F,

$C_{quad} = (2)(444.00)-(1)(537.16)-(2)(562.50)-(1)652.46)-(2)(767.64)$
$= 108.66$

$C_{quad} = 11806.996$

$MS_{quad} = C_{quad}/n\Sigma c^2 = 11806.996/((10)(14)) = 84.3356$

$F_{quad} = MS_{quad}/MS_{residual} = 84.3356/109.84$

$= 0.7676$

which agrees with the F for the quadratic trend in the SPSSX printout.

5.4 Example of Duncan's Multiple-Range Test.

SPSSX.

The SPSSX command file is shown in Exhibit 14. This command file uses the data set XXDATA, transforms the data using the arcsin transformation, compares years using a One-way ANOVA model, and conducts a Duncan's Multiple-Range Test. The only reason for using the One-way ANOVA model is that the Duncan's test has to be run with this model in SPSSX. The Duncan's test result generated by this model should be good enough for our purposes, unless the mean square due to the transects is significant, in which case a manual computation can be easily performed to arrive at the Duncan's statistic for the two-way model.

The SPSSX results are shown in Exhibit 15. The results of Duncan's test are best understood by comparing columns versus rows in the printout. Pairwise group comparisons of 1 vs. 2, 2 vs. 3, and 3 vs. 4 are not significantly different, but 4 vs. 5 is. Pairwise comparisons of 1 vs. 3, 2 vs. 4, and 3 vs. 5 are significantly different. Pairwise comparisons of 1 vs. 4, and 2 vs. 5 are significantly different. Pairwise comparison of 1 vs. 5 is also significantly different.

As indicated earlier, this should be good enough if the transect effect is not significant and, hence, the mean square error is pretty much the same for the One-way ANOVA and the Two-way ANOVA (in this example $MS_{error} = 116.63$ for one-way and $MS_{error} = 109.84$ for two-way). If the transect effect is significant, the significant differences in the Duncan's test for a Two-way ANOVA model can be recomputed as follows:

The SPSS printout gives this expression for the significant difference, S,

$$S = 7.6364 \times \text{RANGE} \times \sqrt{(1/N(i)+1/N(j))}$$

which is equivalent to

$$S = \sqrt{(MS_{error}/2)} \times \text{RANGE} \times \sqrt{(2/N)}$$

Since the $MS_{error} = 109.84$ for the two-way model and N (number of transects) is 10, then, the significant difference expression becomes

$$S = \sqrt{(109.84/2)} \times \text{RANGE} \times \sqrt{(2/10)}$$

Using the RANGE values given in the printout, the values for S become

	2	3	4	5
S	9.4455	9.9426	10.2409	10.4729

Now, let us compare the means. The means are ordered in ascending order,

1	44.40
2	53.71
3	56.25
4	65.24
5	76.76

For contiguous means, use $S_2 = 9.4455$

44.40 - 53.71 = 9.31 , not significant
53.71 - 56.25 = 2.54 , not significant
56.25 - 65.24 = 8.99 , not significant
65.24 - 76.76 = 11.52 , significant

For means two places apart, use $S_3 = 9.9426$

44.40 - 56.25 = 11.85 , significant
53.71 - 65.24 = 11.53 , significant
56.26 - 76.76 = 20.51 , significant

For means three places apart, use $S_4 = 10.2409$

44.40 - 65.24 = 20.84 , significant
53.71 - 76.76 = 23.05 , significant

For means four places apart, use $S_5 = 10.4729$

44.40 - 76.70 = 22.36 , significant

Expressing this in the same graphical fashion as the SPSSX printout,

Means	1	2	3	4	5
1					
2					
3	*				
4	*	*			
5	*	*	*	*	

Notice that the significant differences are the same as in the SPSSX printout, which is to be expected due to the lack of significance of the transect term, and the corresponding similar values of the mean square error terms in the one-way and the two-way models.

STPK and A121/RENO/XMONITOR.

STPK does not have the capability to run Duncan's test. A121/RENO/MONITOR does have the capability to conduct Duncan's test on contiguous means as well as a Two-way ANOVA. The interactive session is shown in Exhibit 16, using data set YYDATA adapted to the format of the program. Notice that the mean squares, F values, and their level of significance for the years, transects, and residual error are identical to those obtained using either SPSSX or STPK for the Two-way ANOVA design. The values for S are slightly different, which appears to be due to the values used in building the Duncan tables in the computer subroutine. The "non-significant groupings" give the comparisons for contiguous means only. Notice that the results agree with the SPSSX printout. Pairwise comparisons of 84 vs. 85, 85 vs. 86, and 86 vs. 87 are not significantly different, but 87 vs. 88 is significantly different.

5.5 Example of Two-way ANOVA with repeated measurements.

SPSSX.

The SPSSX command file is shown in Exhibit 17. This command file uses data set YYDATA, transforms the data using the arcsin transformation, and performs a Two-way ANOVA with repeated measurements on the same plots or transects. Refer to Winer (1971, p.261) for a detailed explanation of the single-factor experimental design with repeated measurements on the same element.

The SPSSX results are shown in Exhibit 18. Although conceptually the repeated measurement design is different from the two-way randomized block design, the results are computationally the same. The within-cells mean square in the test of "between subjects" corresponds to the transect mean square. Similarly, in the test of "within subject," the within-cells mean square corresponds to the residual mean square, and the year mean square is the same in both analyses.

Since there is no advantage to using this design when dealing with only one factor (years) and the results are computationally the same, use a randomized block design even if the same plots or transects are remeasured.

STPK.

STPK does not have the capability to run this design. However, since the Two-way ANOVA design is computationally identical to the design of repeated measurements on the same plot or transect, use the two-way randomized block design.

5.6 Example of Two-way ANOVA with more than one observation per block.

SPSSX.

The SPSSX command file is shown in Exhibit 19. This command file uses the data set DDDATA, transforms the data using the square root transformation, and performs a two-factor analysis of variance with repeated measurements on one factor. Refer to Winer (1971, p.518) for a detailed explanation of the two-factor experiment with repeated measurements on one factor.

The SPSSX results are shown in Exhibit 20. The YEAR and the YEAR x TRANSect interaction mean squares are tested against the residual mean square. The YEAR factor is significant at the 0.000 level, which means that there is a significant difference between the years at that level of significance. The YEAR x TRANSect interaction is only significant at the 0.166 level. The TRANSect effect is tested against the ERROR 1 mean square. The F value shows significance at the 0.026 level.

STPK.

The interactive session is shown in Exhibit 21. The analysis is conducted using a three-factor design and pooling the appropriate mean squares to compute the two error terms. To examine the significance of the year (Y) and the year x transect interaction (YT), we pool the YR and the T x YR term. This results in a POOL1 value of 14.83, which is the same as the RESIDUAL in the SPSSX analysis. To examine the significance of the transect effect (T), we pool the replication (R) and the TR interaction. This results in a POOL2 value of 17.16, which is the same as the ERROR 1 term in the SPSSX printout.

5.7 Example of Chi-square.

SPSSX.

The SPSSX command file is shown in Exhibit 22. This command file uses data set CHDATA, sets up a contingency table, and computes the Chi-square statistic. The hypothesis being tested is that of independence between the rows (cover classes) and the columns (years). This means that rows and columns represent an independent classification, that is, the proportion of each year total that belongs to each cover class is the same for all years. If this is the case, there is no difference between years and the Chi-square statistic will not be significant. If it is not the case, the years are different and the Chi-square statistic will be significant.

The SPSSX results are shown in Exhibit 23. The Chi-square statistic obtained is only significant at the 0.8864 level. Since we are looking for significance at the 0.01 or 0.05 level, we can state that the years are not significantly different at either of those two levels.

STPK.

The interactive session is shown in Exhibit 24. The analysis is conducted using the ONECDATA set. The Chi-square value obtained of 1.149 agrees with the SPSSX printout.

Glossary of Terms

Accuracy.	The closeness of a measured or computed value to its true value.
Alpha level of significance.	Probability of rejecting H_0, given that the H_0 is true; that is, the probability of Type I error.
Alternative Hypothesis, H_1.	A statement that there is a difference between the true value of the parameter of the population sampled and the hypothesized value of the population parameter. This is equivalent to saying that the treatment does have an effect.
Beta level of significance.	Probability of accepting H_0, given that the H_0 is false; that is, the probability of Type II error.
Inference.	The process of making generalizations about a population from one or more samples. **Statistical inference** allows one to assess how reliable such generalizations are (in terms of standard errors, confidence intervals, etc.). **Logical inference** does not allow an assessment of precision.
Key area.	A relatively small portion of a rangeland area selected because of its location, use, or grazing value and used as an area on which to monitor the effects of grazing use. It is assumed that key areas, if properly selected, will reflect the effects of current grazing management over all or a part of a pasture, allotment, or other grazing unit. Since key areas are subjectively located, statistical inferences concerning the population sampled are possible **only** for the key area (or the portion of the key area sampled). Any generalizations concerning the remainder of the pasture or allotmentare logical inferences. This does not mean that such generalizations are not valid, only that there is no way of assessing the degree of error associated with such generalizations.
Null Hypothesis, H_0.	A statement that there is no difference (hence the term "null") between the true value of the parameter of the population sampled and the hypothesized value of the population parameter. This is equivalent to saying that a treatment has no effect.
Parameter.	A number computed from a population.
Population.	Any set or collection of things that has some observable thing about which one wishes information.
Precision.	The closeness of repeated measurements of the same quantity.
Sample.	A portion or subset of a population. A collection of sampling units. Samples are used to represent the population from which the sample is drawn.

Sampling unit.	A subdivision of the population that may be selected (through random sampling) through sampling. The sampling unit may be an individual plant, a transect, or a plot. The sampling units must cover the whole of the population to be sampled and not overlap. A number of sampling units selected through random sampling constitutes a sample.
Statistic.	A number computed from a sample.
Type I error.	The error of wrongly rejecting the null hypothesis, given that the null hypothesis is true (deciding that an ineffective treatment is effective).
Type II error.	The error of failing to reject the null hypothesis, given that the null hypothesis is false (failing to identify that an effective treatment is indeed effective).

Type I and Type II errors illustrated:

		H_0 Accepted	H_0 Rejected
H_0	True	Correct Decision	Type I Error
H_0	False	Type II Error	Correct Decision

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Exhibits

EXHIBIT 1.

ONECDATA Data set

```
7 14 10
14 22 18
7 10 5
```

EXHIBIT 2.

CHDATA Data Set

```
84 1 7
84 2 14
84 3 7
85 1 14
85 2 22
85 3 10
86 1 10
86 2 18
86 3 5
```

EXHIBIT 3.
XXDATA Data Set

```
1 1 7
1 2 13
1 3 13
1 4 13
1 5 8
1 6 9
1 7 14
1 8 7
1 9 5
1 10 9
2 1 12
2 2 13
2 3 10
2 4 17
2 5 8
2 6 18
2 7 11
2 8 14
2 9 10
2 10 15
3 1 10
3 2 14
3 3 12
3 4 14
3 5 17
3 6 17
3 7 15
3 8 10
3 9 13
3 10 15
4 1 16
4 2 20
4 3 16
4 4 10
4 5 11
4 6 16
4 7 19
4 8 18
4 9 16
4 10 17
5 1 20
5 2 20
5 3 14
5 4 20
5 5 18
5 6 18
5 7 16
5 8 17
5 9 19
5 10 20
```


EXHIBIT 4.

YYDATA Data Set

```
1 7 12 10 16 20
2 13 13 14 20 20
3 13 10 12 16 14
4 13 17 14 10 20
5 8 8 17 11 18
6 9 18 17 16 18
7 14 11 15 19 16
8 7 14 10 18 17
9 5 10 13 16 19
10 9 15 15 17 20
```

EXHIBIT 5.

DDDATA Data Set

```
1 1 1 0
1 1 2 9
1 1 3 16
1 2 1 0
1 2 2 1
1 2 3 9
1 3 1 25
1 3 2 25
1 3 3 36
1 4 1 9
1 4 2 16
1 4 3 4
2 1 1 16
2 1 2 25
2 1 3 49
2 2 1 4
2 2 2 16
2 2 3 25
2 3 1 49
2 3 2 36
2 3 3 64
2 4 1 64
2 4 2 36
2 4 3 81
```

EXHIBIT 6.

SPSSX Command File for t-test with independent samples

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/XXDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /YEAR TRANS FREQ
75SET WIDTH=80
80LIST VARIABLES=ALL
90COMPUTE FREQ=FREQ/20.
100COMPUTE FREQ=ARSIN(SQRT(FREQ))
110COMPUTE FREQ=360.*FREQ/(2.*3.1416)
120T-TEST GROUPS=YEAR(1,2)/VARIABLES=FREQ/
180FINISH
190$:ENDJOB
```


EXHIBIT 7.

SPSSX results for t-test with independent samples

- - - - - - - - - - - - - - - - - T - T E S T- - - - - - - - - - - - - - - -

GROUP 1 - YEAR EQ 1.00
GROUP 2 - YEAR EQ 2.00

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
FREQ				
GROUP 1	10	44.4009	9.375	2.965
GROUP 2	10	53.7165	10.297	3.256

		* POOLED VARIANCE ESTIMATE			* SEPARATE VARIANCE ESTIMATE		
F VALUE	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	* T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
1.21	0.784	* -2.12	18	0.049	* -2.12	17.84	0.049

EXHIBIT 8.

SPSSX command file for t-test with paired samples

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/YYDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /TRANS FREQ1 TO FREQ5
75SET WIDTH=80
80LIST VARIABLES=ALL
85DO REPEAT FREQ=FREQ1 TO FREQ5
90COMPUTE FREQ=FREQ/20.
100COMPUTE FREQ=ARSIN(SQRT(FREQ))
110COMPUTE FREQ=360.*FREQ/(2.*3.1416)
115END REPEAT
120T-TEST PAIRS=FREQ1 FREQ2
180FINISH
190$:ENDJOB
```


EXHIBIT 9.

SPSSX results for t-test with paired samples

- - T - T E S T - -

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
FREQ1	10	44.4009	9.375	2.965
FREQ2	10	53.7165	10.297	3.256

(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	*	CORR.	2-TAIL PROB.	*	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
-9.3156	12.960	4.098	*	0.135	0.711	*	-2.27	9	0.049

EXHIBIT 10.

STPK results for t-tests with independent and paired samples

```
STPK

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=1

TO CHANGE TO A DIFFERENT STAT GROUP, TYPE FINISH IN ANSWER TO
  -WHAT ANALYSIS DO YOU WISH TO PERFORM-

TO TERMINATE STATPKG, TYPE END IN ANSWER TO
  -WHICH STAT GROUP WOULD YOU LIKE TO USE-

IS YOUR DATA COMING FROM OTHER THAN TTY *
=YES
ENTER CATALOG FILE STRING FOR DATA FILE
=SC325FM/RANGEMON/YYDATA

DO YOU WISH TO LIST NAMES OF AVAILABLE ANALYSES *
=YES

THE FOLLOWING ANALYSES ARE AVAILABLE IN THIS GROUP..
 EDIT..................... ADD, REPLACE, AND DELETE DATA
 TRANSFORMATION........... LOG, SQUARE ROOT, ETC.
 ELEMENTARY STATISTICS.... MEAN, STANDARD DEVIATION, ETC.
 CORRELATION
 CROSS TABULATION......... FREQUENCY TABLE FOR 2 CROSSED VARIABLES
 SCATTER DIAGRAM
 HISTOGRAM
 LINE PLOT................ VERTICAL LINE PLOT
 RANK CORRELATION
 CHI-SQUARE............... CONTINGENCY TABLE
 T TEST................... TWO SAMPLE MEANS

WHAT ANALYSIS DO YOU WISH TO PERFORM *
=TRANSFORMATION

DO YOU WISH TO READ NEW DATA *
=YES

HOW MANY ROWS IN YOUR DATA MATRIX *
=10
```


EXHIBIT 10 (CONT.)

```
HOW MANY COLUMNS *
=6

SPECIFY INPUT CODE FOR YOUR DATA *
=DF

THE DATA WILL NOW BE READ FROM DISK IN A FREE FORMAT

DO YOU WISH TO PRINT THE DATA JUST READ IN
=YES
      1.000     7.000    12.000    10.000    16.000    20.000
      2.000    13.000    13.000    14.000    20.000    20.000
      3.000    13.000    10.000    12.000    16.000    14.000
      4.000    13.000    17.000    14.000    10.000    20.000
      5.000     8.000     8.000    17.000    11.000    18.000
      6.000     9.000    18.000    17.000    16.000    18.000
      7.000    14.000    11.000    15.000    19.000    16.000
      8.000     7.000    14.000    10.000    18.000    17.000
      9.000     5.000    10.000    13.000    16.000    19.000
     10.000     9.000    15.000    15.000    17.000    20.000

DO YOU WISH TO CHANGE SOME VALUES *
=NO

TYPE TRANSFORMATION CODE *
=10

SPECIFY VARIABLE X AND CONSTANT, AND THE VARIABLE NUMBER ASSIGNED TO
THE TRANSFORMED DATA IN THE FORM  XX/XX.X/XX
=2/0.05/7

TYPE TRANSFORMATION CODE *
=10

SPECIFY VARIABLE X AND CONSTANT, AND THE VARIABLE NUMBER ASSIGNED TO
THE TRANSFORMED DATA IN THE FORM  XX/XX.X/XX
=3/0.05/8

TYPE TRANSFORMATION CODE *
=1

SPECIFY VARIABLE X AND THE VARIABLE NUMBER ASSIGNED TO THE TRANSFORMED
DATA IN THE FORM  XX/XX
=7/9

TYPE TRANSFORMATION CODE *
=1
```

```
SPECIFY VARIABLE X AND THE VARIABLE NUMBER ASSIGNED TO THE TRANSFORMED
DATA IN THE FORM  XX/XX
=8/10

TYPE TRANSFORMATION CODE *
=12

SPECIFY VARIABLE X AND THE VARIABLE NUMBER ASSIGNED TO THE TRANSFORMED
DATA IN THE FORM  XX/XX
=9/11

TYPE TRANSFORMATION CODE *
=12

SPECIFY VARIABLE X AND THE VARIABLE NUMBER ASSIGNED TO THE TRANSFORMED
DATA IN THE FORM  XX/XX
=10/12

TYPE TRANSFORMATION CODE *
=10

SPECIFY VARIABLE X AND CONSTANT, AND THE VARIABLE NUMBER ASSIGNED TO
THE TRANSFORMED DATA IN THE FORM  XX/XX.X/XX
=11/57.29578/13

TYPE TRANSFORMATION CODE *
=10

SPECIFY VARIABLE X AND CONSTANT, AND THE VARIABLE NUMBER ASSIGNED TO
THE TRANSFORMED DATA IN THE FORM  XX/XX.X/XX
=12/57.29578/14

TYPE TRANSFORMATION CODE *
=0

HOW MANY VARIABLES DO YOU WISH TO RETAIN *
=14

DO YOU WISH TO PRINT THE DATA MATRIX *
=NO

WHAT ANALYSIS DO YOU WISH TO PERFORM *
=T TEST

DO YOU WISH TO USE THE SAME DATA *
=YES
```



```
SPECIFY CODE OF DESIRED HYPOTHESIS *
=SOS

THE FOLLOWING CODES SIGNIFY HYPOTHESES AVAILABLE FOR TESTING...
 1   MEAN OF A = GIVEN VALUE
 2   MEAN OF A = MEAN OF B, ASSUMING TWO VARIANCES ARE EQUAL
 3   MEAN OF A = MEAN OF B, ASSUMING TWO VARIANCES ARE NOT EQUAL AND
                           SAMPLES ARE SMALL
 4   MEAN OF A = MEAN OF B, WHERE A AND B ARE RELATED

SPECIFY CODE OF DESIRED HYPOTHESIS *
=2

SPECIFY THE COLUMN NUMBERS OF VARIABLES A AND B IN THE FORM AA/BB
=13/14

COMPUTED T VALUE......     2.11535
DEGREES OF FREEDOM....          18

DO YOU WISH TO USE THE SAME DATA BASE TO COMPUTE MORE T VALUES
=YES

SPECIFY CODE OF DESIRED HYPOTHESIS *
=4

SPECIFY THE COLUMN NUMBERS OF VARIABLES A AND B IN THE FORM AA/BB
=13/14

COMPUTED T VALUE......     2.27302
DEGREES OF FREEDOM....           9

DO YOU WISH TO USE THE SAME DATA BASE TO COMPUTE MORE T VALUES
=NO

WHAT ANALYSIS DO YOU WISH TO PERFORM *
=FINISH

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=END
```

Exhibit 11.

SPSSX command file for two-way ANOVA with randomized block design

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/XXDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /YEAR TRANS FREQ
75SET WIDTH=80
80LIST VARIABLES=ALL
90COMPUTE FREQ=FREQ/20.
100COMPUTE FREQ=ARSIN(SQRT(FREQ))
110COMPUTE FREQ=360.*FREQ/(2.*3.1416)
120MANOVA FREQ BY TRANS(1,10) YEAR(1,5)/
130  PRINT=OMEANS(TABLES(CONSTANT YEAR))/
140  PRINT=SIGNIF(SINGLEDF)/
150  PRINT=PARAMETER(ESTIM)/
160  CONTRAST(YEAR)=POLYNOMIAL/
170  DESIGN CONSTANT YEAR TRANS/
180FINISH
190$:ENDJOB
```


EXHIBIT 12.

SPSSX results for two-way ANOVA with randomized block design

```
* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *
COMBINED OBSERVED GRAND MEANS
VARIABLE .. FREQ
        HMEAN
                      WGT.     59.27571
                    UNWGT.     59.27571

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
COMBINED OBSERVED MEANS FOR YEAR
VARIABLE .. FREQ
         YEAR
            1         WGT.     44.40092
                    UNWGT.     44.40092
            2         WGT.     53.71648
                    UNWGT.     53.71648
            3         WGT.     56.25011
                    UNWGT.     56.25011
            4         WGT.     65.24654
                    UNWGT.     65.24654
            5         WGT.     76.76449
                    UNWGT.     76.76449

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

EXHIBIT 12 (CONT.)

* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *

TESTS OF SIGNIFICANCE FOR FREQ USING UNIQUE SUMS OF SQUARES

SOURCE OF VARIATION	SS	DF	MS	F	SIG OF F
RESIDUAL	3954.31	36	109.84		
CONSTANT	175680.48	1	175680.48	1599.39	.000
YEAR	6028.27	4	1507.07	13.72	.000
1ST PARAMETER	5815.16	1	5815.16	52.94	.000
2ND PARAMETER	84.36	1	84.36	.77	.387
3RD PARAMETER	86.55	1	86.55	.79	.381
4TH PARAMETER	42.19	1	42.19	.38	.539
TRANS	1294.05	9	143.78	1.31	.266
1ST PARAMETER	114.71	1	114.71	1.04	.314
2ND PARAMETER	233.38	1	233.38	2.12	.154
3RD PARAMETER	326.20	1	326.20	2.97	.093
4TH PARAMETER	10.33	1	10.33	.09	.761
5TH PARAMETER	282.80	1	282.80	2.57	.117
6TH PARAMETER	46.51	1	46.51	.42	.519
7TH PARAMETER	2.00	1	2.00	.02	.893
8TH PARAMETER	114.47	1	114.47	1.04	.314
9TH PARAMETER	163.64	1	163.64	1.49	.230

ESTIMATES FOR FREQ

--- INDIVIDUAL UNIVARIATE .9500 CONFIDENCE INTERVALS

CONSTANT

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
1	59.2757089	1.48217	39.99242	.00000	56.26972	62.28170

YEAR

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
2	24.1146448	3.31424	7.27607	.00000	17.39305	30.83624
3	2.90447908	3.31424	.87636	.38664	-3.81711	9.62607
4	2.94200420	3.31424	.88769	.38060	-3.77959	9.66360
5	-2.0541185	3.31424	-.61979	.53930	-8.77571	4.66747

TRANS

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
6	-2.1809171	4.44652	-.49048	.62677	-11.19888	6.83705
7	9.57346855	4.44652	2.15302	.03809	.55551	18.59143
8	-5.3315712	4.44652	-1.19904	.23834	-14.34953	3.68639
9	3.27042337	4.44652	.73550	.46680	-5.74754	12.28839
10	-6.2535970	4.44652	-1.40640	.16818	-15.27156	2.76437
11	3.90593692	4.44652	.87843	.38554	-5.11203	12.92390
12	1.75867973	4.44652	.39552	.69479	-7.25928	10.77664
13	-3.9080702	4.44652	-.87891	.38528	-12.92603	5.10989
14	-5.4272780	4.44652	-1.22057	.23018	-14.44524	3.59068

EXHIBIT 13.

STPK results for two-way ANOVA with randomized block design

```
STPK

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=3

TO CHANGE TO A DIFFERENT STAT GROUP, TYPE FINISH IN ANSWER TO
  -WHAT ANALYSIS DO YOU WISH TO PERFORM-

TO TERMINATE STATPKG, TYPE END IN ANSWER TO
  -WHICH STAT GROUP WOULD YOU LIKE TO USE-

IS YOUR DATA COMING FROM OTHER THAN TTY *
=YES
ENTER CATALOG FILE STRING FOR DATA FILE
=SC325/RANGEMON/XXDATA
UNABLE TO ACCESS FILE AS REQUESTED PLEASE RENTER
ERROR STATUS = 400100000000
ENTER CATALOG FILE STRING FOR DATA FILE
=SC325FM/RANGEMON/XXDATA

SPECIFY THE NUMBER OF FACTORS *
=2

SPECIFY ONE-LETTER LABELS FOR EACH FACTOR IN THE FORM X/X/X/...
=Y/T

SPECIFY LEVELS (CATEGORIES) FOR EACH FACTOR IN THE FORM X/X/X/...
=5/10

SPECIFY INPUT CODE FOR YOUR DATA *
=DF

EACH INPUT RECORD SHOULD CONTAIN A SINGLE OBSERVATION PRECEDED BY ITS
IDENTIFING SUBSCRIPTS - ONE FOR EACH FACTOR

THE DATA WILL NOW BE READ FROM DISK IN A FREE FORMAT

DO YOU WISH TO PRINT THE DATA JUST READ IN
=YES
```

FACTOR LEVELS		OBSERVATION
1	1	7.00000
2	1	12.00000
3	1	10.00000
4	1	16.00000
5	1	20.00000
1	2	13.00000
2	2	13.00000
3	2	14.00000
4	2	20.00000
5	2	20.00000
1	3	13.00000
2	3	10.00000
3	3	12.00000
4	3	16.00000
5	3	14.00000
1	4	13.00000
2	4	17.00000
3	4	14.00000
4	4	10.00000
5	4	20.00000
1	5	8.00000
2	5	8.00000
3	5	17.00000
4	5	11.00000
5	5	18.00000
1	6	9.00000
2	6	18.00000
3	6	17.00000
4	6	16.00000
5	6	18.00000
1	7	14.00000
2	7	11.00000
3	7	15.00000
4	7	19.00000
5	7	16.00000
1	8	7.00000
2	8	14.00000
3	8	10.00000
4	8	18.00000
5	8	17.00000
1	9	5.00000
2	9	10.00000
3	9	13.00000
4	9	16.00000
5	9	19.00000
1	10	9.00000
2	10	15.00000
3	10	15.00000
4	10	17.00000
5	10	20.00000

DO YOU WISH TO MAKE ANY CORRECTIONS TO THE DATA *
=NO

DO YOU WISH TO PERFORM DATA TRANSFORMATION
=YES

SPECIFY TRANSFORMATION CODE *
=10

SPECIFY THE VALUE OF THE CONSTANT
=0.05

SPECIFY TRANSFORMATION CODE *
=1

SPECIFY TRANSFORMATION CODE *
=12

SPECIFY TRANSFORMATION CODE *
=10

SPECIFY THE VALUE OF THE CONSTANT
=57.29578

SPECIFY TRANSFORMATION CODE *
=0

FACTOR	LEVEL
Y	5
T	10

GRAND MEAN 59.27585

LINE NUMBER	SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
1	Y	6028.29730	4	1507.07433
2	T	1294.05168	9	143.78352
3	YT	3954.32831	36	109.84245
	TOTAL	11276.67737	49	

DO YOU WISH TO POOL COMPONENTS *
=NO

DO YOU WISH TO COMPUTE F-VALUES *
=YES

EXHIBIT 13 (CONT.)

```
TYPE LINE NUMBER OF MAIN EFFECT OR INTERACTION, AND LINE NUMBER OF
ERROR TERM IN THE FORM XX/XX. TYPE 0/0 WHEN YOU WISH TO STOP
=1/3

F-VALUE.....    13.72033  (D.F.=  4,  36)

TYPE LINE NUMBERS FOR NEXT F CALCULATION
=2/3

F-VALUE.....     1.30900  (D.F.=  9,  36)

TYPE LINE NUMBERS FOR NEXT F CALCULATION
=0/0

DO YOU WISH TO POOL MORE COMPONENTS OR COMPUTE MORE F-VALUES
=NO

DO YOU HAVE OTHER ANALYSIS-OF-VARIANCE PROBLEMS TO SOLVE
=NO

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=END
```


EXHIBIT 14.

SPSSX command file for Duncan's multiple range test

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/XXDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /YEAR TRANS FREQ
75SET WIDTH=80
80LIST VARIABLES=ALL
90COMPUTE FREQ=FREQ/20.
100COMPUTE FREQ=ARSIN(SQRT(FREQ))
110COMPUTE FREQ=360.*FREQ/(2.*3.1416)
120ONEWAY FREQ BY YEAR(1,5)/
150  POLYNOMIAL = 2/
160  RANGES = DUNCAN/
180FINISH
190$:ENDJOB
```

EXHIBIT 15.

SPSSX results for Duncan's multiple range test

- - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - -

VARIABLE FREQ
BY VARIABLE YEAR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	4	6028.2688	1507.0672	12.9218	.0000
LINEAR TERM	1	5815.1609	5815.1609	49.8599	.0000
DEVIATION FROM LINEAR	3	213.1079	71.0360	.6091	.6126
QUAD. TERM	1	84.3600	84.3600	.7233	.3996
DEVIATION FROM QUAD.	2	128.7479	64.3740	.5519	.5797
WITHIN GROUPS	45	5248.3554	116.6301		
TOTAL	49	11276.6242			

EXHIBIT 15 (CONT.)

- - - - - - - - - - - - - - - - - O N E W A Y - - - - - - - - - - - - - -

VARIABLE FREQ
BY VARIABLE YEAR

MULTIPLE RANGE TEST

DUNCAN PROCEDURE
RANGES FOR THE 0.050 LEVEL -

2.85 3.00 3.09 3.16

THE RANGES ABOVE ARE TABLE RANGES.
THE VALUE ACTUALLY COMPARED WITH MEAN(J)-MEAN(I) IS..
7.6364 * RANGE * DSQRT(1/N(I) + 1/N(J))

(*) DENOTES PAIRS OF GROUPS SIGNIFICANTLY DIFFERENT AT THE 0.050 LEVEL

MEAN	GROUP	GRP 1	GRP 2	GRP 3	GRP 4	GRP 5
44.4009	GRP 1					
53.7165	GRP 2					
56.2501	GRP 3	*				
65.2465	GRP 4	*	*			
76.7645	GRP 5	*	*	*	*	

HOMOGENEOUS SUBSETS (SUBSETS OF GROUPS, WHOSE HIGHEST AND LOWEST MEANS DO NOT DIFFER BY MORE THAN THE SHORTEST SIGNIFICANT RANGE FOR A SUBSET OF THAT SIZE)

SUBSET 1

GROUP	GRP 1	GRP 2
MEAN	44.4009	53.7165

SUBSET 2

GROUP	GRP 2	GRP 3
MEAN	53.7165	56.2501

EXHIBIT 15 (CONT.)

```
SUBSET  3

GROUP       GRP 3        GRP 4
MEAN       56.2501      65.2465
- - - - - - - - - - - - - - - - -

SUBSET  4

GROUP       GRP 5
MEAN       76.7645
- - - - - - - - - -
```


EXHIBIT 16.

/RENO/XMONITOR results for Duncan's multiple range test

```
SC325FM/RENO/XMONITOR
INDICATE THE TYPE OF DATA TO BE ENTERED
BY TYPING:
           1 - FOR FREQUENCY AND/OR COVER DATA
           2 - FOR DENSITY DATA
=1
DO YOU WANT TO UPDATE THE DATA BASE?(YES,NO OR NEW)
=NO
ENTER NAME OF DATA BASE FILE
=SC325FM/RANGEMON/ZZBASE
DO YOU WANT TO PRINT THE DATA BASE(YES OR NO)?
=YES

HXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX  1
GAAAAAAXX 5
Y8401011020 7131313 8 914 7 5 9
Y850101102012131017 81811141015
Y8601011020101412141717151013 15
Y870101102016201610111619181617
Y880101102020201420181816171920

ENTER PERCENT LEVEL OF SIGNIFICANCE(5 OR 10)
=5
ENTER KEY AREA NUMBER;
IF ALL KEY AREAS IN ALLOTMENT, ENTER 'ALL'
=ALL
ENTER 'F' FOR FREQUENCY ANALYSIS; 'C' FOR COVER.
=F
DO YOU WANT THE DETAILED STATISTICAL PRINTOUT?(YES OR NO)
=YES
IF YOU WANT THE OUTPUT TO GO TO A PERM FILE, ENTER FILE NAME;
ELSE ENTER 'NO'
=NO
```

EXHIBIT 16 (CONT.)

```
BLM ADMIN UNIT XXXXXXXX ;WILDLIFE XXXXX ;BIG GAME XXXXXXXX
ALLOTMENT XXXX ;PASTURE XX ;KEY XXXX
PLANT SPECIES AAAAAA


TWO-WAY ANOVA RESULTS

     YEAR       RAW MEANS   TRANS. MEANS
       84           49.00        44.4010
       85           64.00        53.7166
       86           68.50        56.2502
       87           79.50        65.2467
       88           91.00        76.7647

SOURCE     DF         SS            MS               F            PROB>F
YEARS       4      6028.2910     1507.0728         13.72          0.0000
TRANS       9      1294.0473      143.7830          1.31          0.2665
ERROR      36      3954.3355      109.8427
TOTAL      49     11276.6738

STANDARD ERROR OF THE MEAN (TRANFORMED)           3.31


DUNCANS MULTIPLE RANGE TEST AT THE 0.05 SIGNIFICANCE LEVEL

SHORTEST SIGNIFICANT RANGE TABLE
(IF A COMPARISON IS TO BE MADE ACROSS M (TRANSFORMED) MEANS,
THE NECESSARY DIFFERENCE FOR SIGNIFICANCE IS S)

   M =          2            3            4            5
   S =        9.578       10.075       10.340       10.606

     YEAR    RAW MEANS TRANS. MEANS      NON-SIGNIFICANT GROUPINGS
       88       91.00      76.7647
       87       79.50      65.2467    *
       86       68.50      56.2502    **
       85       64.00      53.7166     **
       84       49.00      44.4010      *

DO YOU WANT TO MAKE ANOTHER RUN(YES OR NO)?
=NO
```


EXHIBIT 17.

SPSSX command file for two-way ANOVA with repeated measurements

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/YYDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /TRANS FREQ1 TO FREQ5
75SET WIDTH=80
80LIST VARIABLES=ALL
85DO REPEAT FREQ=FREQ1 TO FREQ5
90COMPUTE FREQ=FREQ/20.
100COMPUTE FREQ=ARSIN(SQRT(FREQ))
110COMPUTE FREQ=360.*FREQ/(2.*3.1416)
115END REPEAT
120MANOVA FREQ1 TO FREQ5/
122  WSFACTORS=YEAR(5)/
124  WSDESIGN=YEAR/
126  ANALYSIS(REPEATED)/
130  PRINT=OMEANS(VARIABLES(FREQ1 TO FREQ5) TABLES(CONSTANT))/
140  PRINT=SIGNIF(UNIV)/
150  PRINT=PARAMETER(ESTIM)/
155  PRINT=TRANSFORM/
160  CONTRAST(YEAR)=POLYNOMIAL/
170  DESIGN/
180FINISH
190$:ENDJOB
```

EXHIBIT 18.

SPSSX results for two-way ANOVA wit' ·peated measurements

```
* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *
COMBINED OBSERVED GRAND MEANS
VARIABLE .. FREQ1
        HMEAN
                  WGT.     44.40092
                UNWGT.     44.40092

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
VARIABLE .. FREQ2
        HMEAN
                  WGT.     53.71648
                UNWGT.     53.71648

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
VARIABLE .. FREQ3
        HMEAN
                  WGT.     56.25011
                UNWGT.     56.25011

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
VARIABLE .. FREQ4
        HMEAN
                  WGT.     65.24654
                UNWGT.     65.24654

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
VARIABLE .. FREQ5
        HMEAN
                  WGT.     76.76449
                UNWGT.     76.76449

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```


61

EXHIBIT 18 (CONT.)

```
* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *
TESTS OF BETWEEN-SUBJECTS EFFECTS.

 TESTS OF SIGNIFICANCE FOR T1 USING UNIQUE SUMS OF SQUARES
 SOURCE OF VARIATION          SS       DF        MS          F  SIG OF F

 WITHIN CELLS              1294.05       9    143.78
 CONSTANT                175680.48       1 175680.48    1221.85      .000
 ESTIMATES FOR T1
 --- INDIVIDUAL UNIVARIATE .9500 CONFIDENCE INTERVALS
 CONSTANT

  PARAMETER      COEFF.  STD. ERR.    T-VALUE     SIG. T LOWER -95%  CL- UPPER

        1   132.544515    3.79187   34.95491     .00000 123.96671  141.12232

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```


62

EXHIBIT 18 (CONT.)

* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *
TESTS INVOLVING 'YEAR' WITHIN-SUBJECT EFFECT.

AVERAGED TESTS OF SIGNIFICANCE FOR FREQ USING UNIQUE SUMS OF SQUARES

SOURCE OF VARIATION	SS	DF	MS	F	SIG OF F
WITHIN CELLS	3954.31	36	109.84		
YEAR	6028.27	4	1507.07	13.72	.000

ESTIMATES FOR T2
--- INDIVIDUAL UNIVARIATE .9500 CONFIDENCE INTERVALS
YEAR

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
1	-22.884498	3.70785	-6.17191	.00016	-31.27223	-14.49676

- -

ESTIMATES FOR T3
--- INDIVIDUAL UNIVARIATE .9500 CONFIDENCE INTERVALS
YEAR

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
1	-5.6062508	2.58240	-2.17095	.05802	-11.44804	.23554

- -

ESTIMATES FOR T4
--- INDIVIDUAL UNIVARIATE .9500 CONFIDENCE INTERVALS
YEAR

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
1	-1.7700235	2.67441	-.66184	.52466	-7.81995	4.27990

- -

ESTIMATES FOR T5
--- INDIVIDUAL UNIVARIATE .9500 CONFIDENCE INTERVALS
YEAR

PARAMETER	COEFF.	STD. ERR.	T-VALUE	SIG. T	LOWER -95%	CL- UPPER
1	6.67559673	4.04567	1.65006	.13333	-2.47633	15.82753

- -

EXHIBIT 19.

SPSSX command file for two-way ANOVA with more than one observation per block

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/DDDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /TRANS YEAR REPL DENS
74SET WIDTH=80
75LIST VARIABLES=ALL
76COMPUTE DENS=SQRT(DENS)
120MANOVA DENS BY REPL(1,3) TRANS(1,2) YEAR(1,4)/
130  PRINT=OMEANS(TABLES(CONSTANT YEAR))/
140  PRINT=SIGNIF(UNIV)/
170  DESIGN=REPL WITHIN TRANS=1,TRANS VS 1,YEAR VS RESIDUAL,
175         YEAR BY TRANS VS RESIDUAL/
180FINISH
190$:ENDJOB
```

EXHIBIT 20.

SPSSX results for two-way ANOVA with more than one observation per block

```
* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *
COMBINED OBSERVED GRAND MEANS
VARIABLE .. DENS
       HMEAN
                  WGT.      4.45833
                UNWGT.      4.45833

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

COMBINED OBSERVED MEANS FOR YEAR
VARIABLE .. DENS
        YEAR
          1       WGT.      3.83333
                UNWGT.      3.83333
          2       WGT.      2.50000
                UNWGT.      2.50000
          3       WGT.      6.16667
                UNWGT.      6.16667
          4       WGT.      5.33333
                UNWGT.      5.33333

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


* * * * * * A N A L Y S I S   O F   V A R I A N C E -- DESIGN   1 * * * * * *
TESTS OF SIGNIFICANCE FOR DENS USING UNIQUE SUMS OF SQUARES
SOURCE OF VARIATION            SS      DF        MS         F  SIG OF F

RESIDUAL                    14.83      12      1.24
YEAR                        47.46       3     15.82     12.80      .000
YEAR BY TRANS                7.46       3      2.49      2.01      .166

ERROR 1                     17.17       4      4.29
TRANS                       51.04       1     51.04     11.89      .026
```


EXHIBIT 21

STPK results for two-way ANOVA with more than one observation per block

```
STPK

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=3

TO CHANGE TO A DIFFERENT STAT GROUP, TYPE FINISH IN ANSWER TO
  -WHAT ANALYSIS DO YOU WISH TO PERFORM-

TO TERMINATE STATPKG, TYPE END IN ANSWER TO
  -WHICH STAT GROUP WOULD YOU LIKE TO USE-

IS YOUR DATA COMING FROM OTHER THAN TTY *
=YES
ENTER CATALOG FILE STRING FOR DATA FILE
=SC325FM/RANGEMON/DDDATA

SPECIFY THE NUMBER OF FACTORS *
=3

SPECIFY ONE-LETTER LABELS FOR EACH FACTOR IN THE FORM X/X/X/...
=T/Y/R

SPECIFY LEVELS (CATEGORIES) FOR EACH FACTOR IN THE FORM X/X/X/...
=2/4/3

SPECIFY INPUT CODE FOR YOUR DATA *
=DF

EACH INPUT RECORD SHOULD CONTAIN A SINGLE OBSERVATION PRECEDED BY ITS
IDENTIFING SUBSCRIPTS - ONE FOR EACH FACTOR

THE DATA WILL NOW BE READ FROM DISK IN A FREE FORMAT

DO YOU WISH TO PRINT THE DATA JUST READ IN
=YES
```

FACTOR LEVELS			OBSERVATION
1	1	1	0.
2	1	1	16.00000
1	2	1	0.
2	2	1	4.00000
1	3	1	25.00000
2	3	1	49.00000
1	4	1	9.00000
2	4	1	64.00000
1	1	2	9.00000
2	1	2	25.00000
1	2	2	1.00000
2	2	2	16.00000
1	3	2	25.00000
2	3	2	36.00000
1	4	2	16.00000
2	4	2	36.00000
1	1	3	16.00000
2	1	3	49.00000
1	2	3	9.00000
2	2	3	25.00000
1	3	3	36.00000
2	3	3	64.00000
1	4	3	4.00000
2	4	3	81.00000

DO YOU WISH TO MAKE ANY CORRECTIONS TO THE DATA *
=NO

DO YOU WISH TO PERFORM DATA TRANSFORMATION
=YES

SPECIFY TRANSFORMATION CODE *
=SOS

THE FOLLOWING CODES SIGNIFY TYPES OF TRANSFORMATIONS..
1 SQUARE ROOT OF X
2 COMMON LOG OF X
3 NATURAL LOG OF X
4 EXPONENTIAL OF X

9 X + C (C IS A CONSTANT.)
10 X * C
11 1 / X
12 ARCSIN OF X
13 X ** C
0 NO MORE TRANSFORMATION

SPECIFY TRANSFORMATION CODE *
=1

SPECIFY TRANSFORMATION CODE *
=0

FACTOR	LEVEL
T	2
Y	4
R	3

GRAND MEAN 4.45833

LINE NUMBER	SOURCE OF VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE
1	T	51.04167	1	51.04167
2	Y	47.45833	3	15.81944
3	TY	7.45833	3	2.48611
4	R	14.58333	2	7.29167
5	TR	2.58333	2	1.29167
6	YR	9.41667	6	1.56944
7	TYR	5.41667	6	0.90278
	TOTAL	137.95833	23	

DO YOU WISH TO POOL COMPONENTS *
=YES

HOW MANY COMPONENTS IN POOL 1. TYPE 0 WHEN YOU WISH TO STOP *
=2

TYPE THE LINE NUMBERS OF THESE COMPONENTS IN THE FORM X/X/X/...
=6/7

LINE NO.				
8	POOL 1	14.83333	12	1.23611

HOW MANY COMPONENTS IN POOL 2
=2

TYPE THE LINE NUMBERS OF THESE COMPONENTS IN THE FORM X/X/X/...
=4/5

LINE NO.				
9	POOL 2	17.16667	4	4.29167

HOW MANY COMPONENTS IN POOL 3
=0

EXHIBIT 21 (CONT)

```
DO YOU WISH TO COMPUTE F-VALUES *
=YES

TYPE LINE NUMBER OF MAIN EFFECT OR INTERACTION, AND LINE NUMBER OF
ERROR TERM IN THE FORM XX/XX. TYPE 0/0 WHEN YOU WISH TO STOP
=2/8

F-VALUE.....    12.79775  (D.F.=  3,  12)

TYPE LINE NUMBERS FOR NEXT F CALCULATION
=3/8

F-VALUE.....     2.01124  (D.F.=  3,  12)

TYPE LINE NUMBERS FOR NEXT F CALCULATION
=1/9

F-VALUE.....    11.89320  (D.F.=  1,   4)

TYPE LINE NUMBERS FOR NEXT F CALCULATION
=0/0

DO YOU WISH TO POOL MORE COMPONENTS OR COMPUTE MORE F-VALUES
=NO

DO YOU HAVE OTHER ANALYSIS-OF-VARIANCE PROBLEMS TO SOLVE
=NO

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=END
```


EXHIBIT 22.

SPSSX command file for Chi-square test

```
10$$S,J,T,MONI
20$:IDENT:SS01/FENNEC,SC210FKM
30$:SELECT:SPSS/X2.2/MAIN
40$:PRMFL:11,R,S,SC325FM/RANGEMON/CHDATA
50FILE HANDLE DATAINPT /UNIT=11
60DATA LIST FREE FILE=DATAINPT
70  /YEAR CLASS COUNT
75SET WIDTH=80
76LIST VARIABLES=ALL
77WEIGHT BY COUNT
80CROSSTABS VARIABLES=YEAR(84,86) CLASS(1,3)/TABLES=CLASS BY YEAR
90STATISTICS 1
180FINISH
190$:ENDJOB
```

EXHIBIT 23.

SPSSX Results for Chi-square test

```
- - - - - - - - - -   C R O S S T A B U L A T I O N   O F  - - - - - - - - - -
   CLASS
BY  YEAR
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -   PAGE  1 OF  1

                  YEAR
           COUNT  I
                  I                          ROW
                  I                          TOTAL
                  I     84I      85I      86I
CLASS     --------+--------+--------+--------+
               1  I     7  I    14  I    10  I    31
                  I        I        I        I   29.0
                  +--------+--------+--------+
               2  I    14  I    22  I    18  I    54
                  I        I        I        I   50.5
                  +--------+--------+--------+
               3  I     7  I    10  I     5  I    22
                  I        I        I        I   20.6
                  +--------+--------+--------+
          COLUMN       28       46       33      107
           TOTAL     26.2     43.0     30.8    100.0


 CHI-SQUARE    D.F.     SIGNIFICANCE      MIN E.F.     CELLS WITH E.F.< 5
 ----------    ----     ------------      --------     ------------------
    1.14923      4         0.8864           5.757        NONE

NUMBER OF MISSING OBSERVATIONS =      0
```


EXHIBIT 24.

STPK results for Chi-square test

```
STPK

WHICH STAT GROUP WOULD YOU LIKE TO USE,
TYPE A NUMBER FROM 1 TO 5, SOS, OR END. *
=1

TO CHANGE TO A DIFFERENT STAT GROUP, TYPE FINISH IN ANSWER TO
  -WHAT ANALYSIS DO YOU WISH TO PERFORM-

TO TERMINATE STATPKG, TYPE END IN ANSWER TO
  -WHICH STAT GROUP WOULD YOU LIKE TO USE-

IS YOUR DATA COMING FROM OTHER THAN TTY *
=YES
ENTER CATALOG FILE STRING FOR DATA FILE
=SC325FM/RANGEMON/ONECDATA

DO YOU WISH TO LIST NAMES OF AVAILABLE ANALYSES *
=YES

THE FOLLOWING ANALYSES ARE AVAILABLE IN THIS GROUP..
 EDIT..................... ADD, REPLACE, AND DELETE DATA
 TRANSFORMATION........... LOG, SQUARE ROOT, ETC.
 ELEMENTARY STATISTICS.... MEAN, STANDARD DEVIATION, ETC.
 CORRELATION
 CROSS TABULATION......... FREQUENCY TABLE FOR 2 CROSSED VARIABLES
 SCATTER DIAGRAM
 HISTOGRAM
 LINE PLOT................ VERTICAL LINE PLOT
 RANK CORRELATION
 CHI-SQUARE............... CONTINGENCY TABLE
 T TEST................... TWO SAMPLE MEANS

WHAT ANALYSIS DO YOU WISH TO PERFORM *
=CHI-SQUARE

DO YOU WISH TO READ NEW DATA *
=YES

HOW MANY ROWS IN YOUR DATA MATRIX *
=3

HOW MANY COLUMNS *
=3
```

EXHIBIT 24 (CONT.)

```
SPECIFY INPUT CODE FOR YOUR DATA *
=DF

THE DATA WILL NOW BE READ FROM DISK IN A FREE FORMAT

DO YOU WISH TO PRINT THE DATA JUST READ IN
=YES
     7.000    14.000    10.000
    14.000    22.000    18.000
     7.000    10.000     5.000

DO YOU WISH TO CHANGE SOME VALUES *
=NO

DO YOU WISH TO PRINT EXPECTED FREQUENCIES
=YES

EXPECTED FREQUENCY IN EACH CELL

     8.1   13.3    9.6

    14.1   23.2   16.7

     5.8    9.5    6.8

CHI-SQUARE...........   1.149
DEGREES OF FREEDOM...       4

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE September 1992

3. REPORT TYPE AND DATES COVERED Final

4. TITLE AND SUBTITLE
Statistical Considerations in Rangeland Monitoring

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of the Interior
Bureau of Land Management Service Center
P.O. Box 25047
Denver, CO 80225-0047

8. PERFORMING ORGANIZATION REPORT NUMBER
TR 4400-8
BLM/SC/PT-92/010+4400

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of the Interio
Bureau of Land Management Washington Office (WO-221)
1849 C Street, N.W. - Room 204 LS
Washington, D.C. 20240

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This Technical Reference deals with the statistical aspects of rangeland monitoring and is intended to help the BLM range conservationist in planning, analyzing, interpreting, and evaluating monitoring studies. It is not a statistics cookbook and assumes a level of knowledge of statistical analysis comparable to what most college graduates are exposed to during their undergraduate training. The material covered in this Technical Reference is divided into five sections. Chapter 1 highlights the statistical topics required to analyze monitoring data and gives appropriate references. Chapter 2 addresses the underlying statistical issues of rangeland monitoring. Chapters 3 and 4 deal with the specific methods used for trend and utilization studies. Chapter 5 shows examples of data analysis.

14. SUBJECT TERMS
Rangeland Monitoring, Range Conservation, Range Management, Bureau of Land Management, Public Lands, Public Land Management, Statistics

15. NUMBER OF PAGES 73

16. PRICE CODE

17. SECRURITY CLASSIFICATION OF REPORT	18. SECRURITY CLASSIFICATION OF THIS PAGE	19. SECRURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

☆U.S. GOVERNMENT PRINTING OFFICE: 1993 - 774-003/62013