Informational Leaflet 7

THE USE OF STATISTICS IN WILDLIFE RESEARCH

By:

Donald B. Siniff
Division of Biological Research
Juneau, Alaska

and

David R. Klein
Division of Game
Juneau, Alaska

January 5, 1962

STATE OF ALASKA
WILLIAM A. EGAN - GOVERNOR

DEPARTMENT OF
FISH AND GAME
WALTER KIRKNESS - COMMISSIONER
SUBPORT BUILDING, JUNEAU

INFORMATIONAL LEAFLET NO. 7

The Use of Statistics in Wildlife Research

Donald B. Siniff and David R. Klein

Alaska Department of Fish and Game
January 5, 1962

THE USE OF STATISTICS IN WILDLIFE RESEARCH

Donald B. Siniff and David R. Klein
Alaska Department of Fish and Game

Most of us in the field of wildlife have been guilty during some phases of our work of both the misuse and the incomplete use of data. Plato said, "If arithmetic, mensuration, and weighing be taken away from any art, that which remains will not be much." This is perhaps more true today than it was in Plato's day when experimental sciences were virtually nonexistent. The era of the descriptive naturalist is over and it behooves all of us, if we are to think of ourselves as biologists, to become familiar with and employ mathematical interpretations of our research data. There is virtually no study in modern field biology that will not benefit by an intelligent statistical approach during both the initial stages of planning and the evaluation of results. This is not to say that biologists should be subservient to the statistician or that statistics are a cure-all for poor data. Remember that "figure" and "fictitious" both derive from the same Latin root.

Perhaps most essential to the proper use of statistical methods of analysis in research is advance planning. Before you begin a research project sufficient time should be devoted to planning and organization of the work so that you know ahead of time the types of statistical analyses intended for the data, the characteristics required of the data to render it suitable for analysis and the shortcomings or limitations which may be inherent to the methods of data collection. Data resulting from this type of advance planning or experimental design will readily yield to analysis, will be immensely more meaningful than data gathered with no prior plans for their treatment and will eliminate the frustration that is encountered when one tries to salvage information from poorly gathered data.

You, as biologists, are not expected to be professional biometricians; competence in the field of biology is demanding enough to occupy the major portion of one's lifetime. However, if you are to intelligently plan your projects and outline your statistical problems in a manner that is understandable to a professional statistician you must have a broad understanding of the basic essentials of statistical analysis. In addition, a workable knowledge of the simpler and more frequently used statistical tests will greatly aid your work and render your data more meaningful. We have included in this report examples of data treated by such useful statistical tests as chi-square and the "t" test with notes on the limitations of the more commonly used arithmetical parameters. In addition there are several excellent texts on statistical analysis and we have found the following three to be particularly readable for persons with limited mathematical background.

Bailey, N.T.J. 1959. Statistical methods of biology. J. Wiley, N.Y., 200 p.

Simpson, G.G., A. Roe, and R.C. Lewontin. 1960. Quantitative zoology. Harcourt, Brace, N.Y., 440 p.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics, with special reference to biological sciences. McGraw-Hill, N.Y., 481 p.

The reporting of the results of studies involving the interpretation of data requires a certain amount of discretion. One of the most frequently encountered errors in technical report writing is that of listing decimal fractions to several places when the degree of refinement of the data does not justify it. Such values should always be rounded off to conform to the limitations of the data. Similarly percentiles should be used with caution as they mask the reliability of the data. For example "55 percent hunter success" can have completely different meaning if only twenty hunters are interviewed rather than several hundred. Possible confusion can be avoided by always indicating sample size in tables and charts when percentiles and ratios are used. The listing of sex ratios should be standardized and rather than indicating these on the basis of 100 females (i.e., 82 males:100 females) such ratios should be calculated on the basis of percent males to percent females. There has been considerable confusion over this point, however, the time honored practice of recording ratios of males per 100 females poses awkward problems in calculating confidence limits and such limits are asymmetrical. The Journal of Wildlife Management finally altered its policy in 1957 (Vol. 21, page 347) and now recommends the percent ratio system. The use of "significant" and "correlation" in technical reports should be restricted to those cases where they refer to the results of statistical analyses. "Significant" generally refers to the 0.05 level of reliability while "highly significant" indicates a 0.01 level.

Reporting of data is usually best accomplished through the use of graphs, charts, and tables. When graphs or charts incorporate all the essential data (or enough to allow it to be recalculated) supporting tables are not necessary. Likewise, tables, graphs and charts, with reference to them in the text, are frequently all that is necessary for the presentation of data in a report. Lengthy reviews of the data in the text are difficult to follow and detract from the quality of the report.

Statistical methods of analysis should be looked upon as neither abstract and incomprehensible mathematical blinds used by ivory tower scientists nor as crutches to support weak data but as essential and useful tools of the wildlife worker.

Chi-square is usually used to test the independence of two classifications. This test is sometimes called a test of association. The null hypothesis is that the variates or attributes are independent. Consider the following example.

These data are from aerial counts of brown bears on the Alaska Peninsula. The interest is whether you count a different composition at different times of the day, i.e., the null hypothesis being that composition of the counts is independent of the time of day the counts are made.

	Sows		Cubs		Yearlings		Other		
Hours	O	E	O	E	O	E	O	E	Total
-10:00	60	58.8	75	72.6	52	51.4	146	150.2	333
10:01-12:00	55	59.2	58	73.0	64	51.7	158	151.1	335
10:01-14:00	54	58.0	61	71.5	54	50.6	159	148.0	328
14:01-16:00	73	64.5	98	79.5	44	56.3	150	164.7	365
16:01-22:00	58	59.5	78	73.4	48	52.0	153	152.0	337
TOTAL	300		370		262		766		1698

O = Observed
E = Expected

The expected values are based on marginal totals. Thus, the expected values for sows were obtained as follows:

Expected values by hours:

-10:00 $\frac{300 \times 333}{1698} = 58.8$

10:01-12:00 $\frac{300 \times 335}{1698} = 59.2$

12:01-14:00 $\frac{300 \times 328}{1698} = 58.0$

14:01-16:00 $\frac{300 \times 365}{1698} = 64.5$

16:01-22:00 $\frac{300 \times 337}{1698} = 59.5$

The other expected values are obtained in like fashion only using the appropriate marginal totals.

The chi-square values are obtained by: $\frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$

and are listed below:

Chi-Square values						Total
	.024	0.79	.007	.117		
	.298	3.082	2.926	.315		
	.276	1.542	.256	.818		
	1.120	4.305	2.687	1.312		
	.038	.288	.308	.007		
TOTAL	1.756	9.296	6.184	2.569	Sum of the chi-square values:	19.805

The number of degrees of freedom are (number of columns - 1) x (number of rows - 1) or in this case (4-1) x (5-1) = 12. d.f. Generally, the .05 level of significance is used in biological work. To find the rejection region, go to Table of Chi-Square, find the appropriate degree of freedom and read across to the 0.5 level. In this case this value is 21.026. If the calculated value is less than this value we do not reject the hypothesis, but if it is greater than this value we reject the hypothesis. Since in this example the calculated value is 19.805 the hypothesis is not rejected. It is found that composition of the counts are independent of the time of day the counts are made.

The "t" test is generally used to determine if differences in sample means from two populations is caused by sampling error or whether there actually is a difference between the population means. In the following test it will be assumed the variances of the two populations are the same and this is usually a correct assumption when comparing populations within Alaska. There is a procedure for treating populations with unequal variances but it will not be discussed here.

The following are hypothetical weights of 1-1/2 year old deer from two areas. It is of interest whether the mean weight of one population is actually different from the mean weight for the other area, therefore, the null hypothesis is that the population means are equal.

Hypothetical weights of 1-1/2 year-old deer from two areas:

Area 1	Area 2
57.8	62.2
56.2	58.7
61.9	63.1
54.4	62.5
53.6	59.8
56.4	59.2
53.2	

Sum of the weights from Area 1 is: $\Sigma X_1 = 393.5$

Sum of the weights from Area 2 is: $\Sigma X_2 = 367.5$

Number from Area 1 in the sample is: $n_1 = 7$

Number from Area 2 in the sample is: $n_2 = 6$

The mean of Area 1 is: $\bar{X}_1 = 56.21$

The mean of Area 2 is: $\bar{X}_2 = 61.25$

Calculate:

$$\Sigma X_1^2 = (57.8)^2 + (56.2)^2 + (61.9)^2 + (54.4)^2 + (53.6)^2 + (56.4)^2 + (53.2)^2 = 22{,}174.41$$

$$\Sigma X_2^2 = (62.2)^2 + (58.7)^2 + (63.1)^2 + (62.5)^2 + (59.8)^2 + (59.2)^2 = 22{,}535.87$$

To obtain a common variance it is necessary to calculate:

$$\Sigma x_1^2 = \Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n_1} = 22{,}174.41 - \frac{(393.5)^2}{7} = 54.09$$

$$\Sigma x_2^2 = \Sigma X_2^2 - \frac{(\Sigma X_2)^2}{n_2} = 22{,}535.87 - \frac{(367.5)^2}{6} = 26.50$$

The estimate of a common variance is:

$$s^2 = \frac{\Sigma x_1^2 + \Sigma x_2^2}{(n_1-1)+(n_2-1)} = \frac{54.09 + 26.50}{6 + 5} = 7.33$$

The degrees of freedom are calculated by:

$(n_1 - 1) * (n_2 - 1) = 11$ degrees of freedom (d.f.) for this example.

The standard deviation appropriate to the difference between the sample mean is:

$$s_{\bar{d}} = \sqrt{s^2 \frac{(n_1 + n_2)}{n_1 n_2}} = \sqrt{7.33 \frac{(7+6)}{42}} = \sqrt{2.27} = 1.51$$

So that to obtain a "t" value for the test of the hypothesis of equal means:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{d}}} = \frac{56.21 - 61.25}{1.51} = -3.33$$

To obtain the rejection region, the value for 11 degrees of freedom at the .05 level is read from a "t" table. This value is 2.20, therefore the rejection region lies outside of the range of -2.20 and +2.20. Since -3.33 falls in the rejection region the hypothesis of equal population means is rejected.

Two of the most common parameters used when dealing with a sample from a population are the mean and variance. Each of these, which are observed from the sample, are estimates of the true mean and true variance found in the population. These two parameters should be used when a sample from the population is used to make statements about the population. When using the parameters the character which is being studied is usually assumed to be normally distributed within the population.

If the mean is presented alone, much information is concealed and is often misleading. From a population of large size many samples may be drawn and in many cases the samples will exhibit different means. If the mean of one sample is used to approximate the true population mean some measure must be made of how accurate this sample mean is in representing the true population mean. To do this the standard error of the mean is often employed. This quantity is a measure of the spread the means of many samples from the same population will exhibit. For sample sizes of more than thirty it is generally accepted that plus and minus two standard errors from the sample mean will include the population mean 95 times out of 100. When using the mean of a sample some consideration certainly should be given to presenting the standard error or at least the sample size from which the mean is obtained.

To help clarify the above discussion, definitions of variance, standard deviation, variance of the mean, and standard error of a mean are given below. The values used in these definitions are from the sample of 1-1/2 year-old deer weights from Area 1, used in explanation of the "t" test.

Variance: This quantity is a measure of dispersion of the individuals or character under study in the population. The variance for the sample is denoted by s^2, and the variance for the population is denoted by σ^2. For Area 1 deer weights:

$$s^2 = \frac{\Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n_1}}{n_1 - 1} = \frac{22{,}174.41 - \frac{(393.5)^2}{7}}{6} = 9.02$$

Standard deviation: This quantity is the positive square root of the variance. This quantity is useful for describing confidence limits of a sample in relation to the individuals of the population. For the sample the standard deviation is denoted by s and for the population it is denoted by σ. For Area 1 deer weights:

$$s = \sqrt{s^2} = \sqrt{9.02} = 3.0$$

Variance of the mean: This quantity is the variance divided by the sample size. This quantity is a measure of the dispersion of the means of samples drawn from the population. For the sample this quantity denoted by $s^2_{\bar{x}}$ and for the population it is denoted by $\sigma^2_{\bar{x}}$.

For Area 1 deer weights:

$$s^2_{\bar{x}} = \frac{s^2}{n} = \frac{9.02}{7} = 1.29$$

Standard error of a mean: This quantity is the positive square root of the variance of the mean. It is used for describing the relationship of the true mean to the means of samples which may be drawn from the population. This quantity is often called the standard deviation of a mean, or just standard error. For the sample it is denoted by $s_{\bar{x}}$ and for the population it is denoted by $\sigma_{\bar{x}}$. For Area 1 deer weights:

$$s_{\bar{x}} = \sqrt{\frac{s^2}{n}} = \sqrt{s^2_{\bar{x}}} = \sqrt{1.29} = 1.13$$

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-6077, (TDD) 907-465-3646, or (FAX) 907-465-6078.