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A VIGOR MEASUREMENT METHOD
FOR DETERMINING TRENDS IN THE
CONDITION OF KEY FORAGE BUNCHGRASSES
ON MONTANA ELK RANGES

by

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CONTENTS

	Page	Section
Introduction	4	
Use of the Method	4	
Materials Used	4	1
Period and frequency of use	5	2
Use on seasonal ranges	5	3
Selection of a key forage bunchgrass	5	4
Selection of sites for using the method	5	5
Establishment of plots on sites	5	6
Number of plots established	5	7
Procedure for laying out a plot	6	8
Numbers of plants selected for measurement	6	9
Procedure for selecting plants to be measured	6	10
Figure 1. - Physical features of a plot	7	
Vigor measurements obtained from plants	8	11
Units of measurement	8	12
Procedures of measurement	8	13
Time required to lay out and measure a plot	8	14
Figure 2. - Field form for recording measurements	9	
Figure 3. - Bunchgrass form classes	11	
Compilation of data	12	15
Reliability standards for form class percentages	12	16
Reliability standards for means	13	17
Procedure for calculating additional numbers of plants needed to satisfy reliability standards	14	18

	Page	Section
Procedure for comparing initial and subsequent form class percentages	14	19
Procedure for comparing initial and subsequent basal area and leaf height means	15	20
Analysis of data	16	21
Possible extensions in the method	17	22
Table 1. - 95% confidence intervals	18	
Table 2. - Chi-square values	19	
Table 3. - t-values	19	
Literature Cited	20	

A VIGOR MEASUREMENT METHOD FOR DETERMINING TRENDS IN THE
CONDITION OF KEY FORAGE BUNCHGRASSES ON MONTANA ELK RANGES¹

Glen F. Cole

Introduction

The method is a procedure for measuring the vigor of key forage bunchgrasses. Initial and subsequent vigor measurements are compared to determine trends in bunchgrass condition.

On the ranges where the method has been used, Idaho fescue (Festuca idahoensis) was selected as a key forage bunchgrass. Selection was based on observations of elk use and measurements of plants inside and outside exclosures. This bunchgrass appears to be very palatable to elk and on most Montana ranges it is abundant enough to serve as an important forage source. Buechner (1952) concluded that Idaho fescue was a preferred elk forage on a winter range in Washington.

The ecological basis for the method was suggested from a review of literature on grass responses to herbage removals (Blaisdell and Pechanec 1949, Heady 1950, Evanco and Peterson 1955, and others). Sampling procedures were designed with the assistance of Dr. Bernard Ostle, Professor of Mathematics, Montana State College. The method was used by the author and other personnel of the Montana Fish and Game Department during 1956. Revisions and extensions were made on the basis of field observations and measurements. While it has had only limited use, the method is indicated to be suitable for measuring short term trends in bunchgrass condition. Additional revisions and extensions are expected as more experience is gained. Use of the method is described here so that others may use it as it is, or modify it to suit their own conditions.

Use of the Method

1. Materials used.

The materials needed to use the method are as follows:

- 1 steel rule graduated in tenths of inches
- 1 one hundred foot tape
- 1 surveyor's compass
- 1 six pound hammer
- 1 six foot steel post and four 18 inch steel stakes
for each plot established
- 12 sharpened wood laths

¹A contribution from Federal Aid in Wildlife Restoration, Montana Project W-37-R. Thanks are extended to Dr. Bernard Ostle for reviewing the report.

The compass is used to maintain right angles on plot corners. The 100-foot tape may also be used to maintain right angles. Distances of 15, 20, and 25 feet are used to form the three sides of a right triangle.

2. Period and frequency of use.

The method is used after bunchgrass plants have matured and before the plants are covered by snow. This period is roughly between August 15 and October 15 in Montana. Annual or biennial measurements are recommended.

3. Use on seasonal ranges.

The method may be used as described on ranges grazed during the spring, fall and winter. On ranges grazed during the summer, take-down exclosures must be employed to protect the plants to be measured.*

4. Selection of a key forage bunchgrass.

A key forage bunchgrass should be palatable to elk, serve as an important source of forage and have a definite bunchgrass life form. In practice, proper use on a key forage bunchgrass should reflect proper use, or something less than proper use, on other important forage grasses.

The palatability of a bunchgrass may be indicated by recording frequencies of plant use at elk feeding sites (Brazda 1953). The importance of a palatable bunchgrass as a forage source may be indicated by observations of abundance or by forage inventory methods such as clipping or weight estimates (Pechanec and Pickford 1937). Suitability of bunchgrass life forms is determined by observation. Bunchgrass clumps should be compact units which have definite basal areas. Some of the bunchgrasses found to have suitable life forms on Montana elk ranges were Idaho fescue, rough fescue (Festuca scabrella), and bluebunch wheatgrass (Agropyron spicatum).

5. Selection of sites for using the method.

Sites where a key forage bunchgrass is furnishing forage to elk are selected on key areas of elk range. Selections may be based on observed use of the sites by elk or on indications of use from plant utilization and/or pellet groups.

6. Establishment of plots on sites.

Permanent 100 by 250 foot plots are established on selected sites. Care is taken that each plot represents an ecological entity such as a ridge top, slope or flat. This is necessary to isolate plant variations due to differences in soil or moisture relations.

7. Number of plots established.

The number of plots established on a range is left to the discretion of management personnel. The different vegetational types and the pattern

*See 22 (Possible extensions of the method).

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of elk use should be considered. Costello and Klipple (1939) point out that numbers of sample plots are dependent upon the heterogeneity of the vegetation on an area rather than the size of an area. The pattern of elk use on ranges is uneven. Areas where forage receives heavy, moderate or light use are usually evident. Relatively few plots will be required if they are strategically located within one vegetational type on heavily used areas. The forage on these heavily used areas should represent a food source which must be maintained in a productive condition. As few as six plots have been used on a 4,000 acre winter elk range in Montana.

8. Procedure for laying out a plot.

The physical features of a plot are shown on figure 1. In laying out a plot a 300-foot base line, where the 50 to 300 foot distance represents one side of the plot, is measured. As the base line is measured the following markers are driven into the ground: a six-foot steel post at the zero foot mark, an 18-inch steel stake and a wood lath at the 50 foot mark, a wood lath at the 100, 150, 200 and 250 foot marks, an 18-inch steel stake and a wood lath at the 300 foot mark.

At the 300 foot mark a 100 foot line is extended 90 degrees from the horizontal base line. This forms the second side of the plot. To form the third side a 250 foot line, parallel to the base line, is measured. As this line is measured the following markers are driven into the ground: an 18-inch steel stake and a wood lath at the zero foot mark, a wood lath at the 50, 100, 150 and 200 foot marks, an 18-inch steel stake and a wood lath at the 250 foot mark. This completes the plot which is outlined by the four 18-inch steel stakes. The offset six-foot steel post and the four 18-inch stakes serve as permanent markers. The wood laths serve to divide the plot into five 50 by 100 foot sections. The laths are removed after the plants on a plot have been measured.

9. Numbers of plants selected for measurement.

Initially, 100 key bunchgrass plants are selected for measurement on each plot. If the data from one plot, or from groups of plots, does not meet reliability standards (see 17 and 18), additional plants are selected for measurement. The procedure for selecting plants may be easily modified to select the desired number.

10. Procedure for selecting plants to be measured.

The procedure requires that a specified course be followed and that a designated number of steps be taken before each plant is selected.

The course followed is shown on figure 1. The wood laths are used as guide posts for walking the crossing diagonal course through each section. The starting point is the corner closest to the six foot steel post. If additional plants are needed after one passing through a plot, the course is retraced (in an opposite direction) until the full 100 plants are selected.

Figure 1. Physical features of a 100 by 250 foot plot and the course walked while sampling plants within the plot. $\odot$ = 6 foot steel post permanent marker, $\circ$ = 18 inch stake permanent marker, X = wood lath temporary marker, $\rightarrow$ = the sampling course.

The steps taken, while following the specified course, range from one to seven. Their sequence is determined from a table of random numbers. Steps are counted from the corner starting point or from points where a previous plant was measured. The number of steps taken before selecting each of the 100 plants is shown on the field form (figure 2). The key bunchgrass plant closest to the toe of the foot completing the designated number of steps is selected. If this plant has a form classed as Normal, Hollow Center or Clump Edge (see 11, on bunchgrass form classes), it is measured. If the plant has a form classed as Seedling or Dead, it is dot-tallied and the next closest Normal, Hollow Center or Clump Edge plant is measured. A penciled circle is then drawn around the form class of this plant. If the random sequence of steps from one to seven fails to sample all portions of a plot or consistently causes the course to be retraced, the range of steps may be adjusted.

11. Vigor measurements obtained from plants.

The measurements considered to reflect the vigor of bunchgrasses are shown on the field form (figure 2). They are bunchgrass form classes, lengths and width of bunchgrass clumps and maximum leaf heights.

The form classes are Normal, Seedling, Hollow Center, Clump Edge and Dead. The Normal class is assigned if all portions of a bunchgrass clump produce leaves (figure 3A), the Seedling class if the length x width measurement is 0.6 inch or less, the Hollow Center class if a "ring" of leaves encircles a dead center by more than one-half the clump circumference (figure 3B), the Clump Edge class if one or more segments of leaves grow on the edge of a clump (figure 3C) and the largest segment does not encircle more than one-half the clump circumference. Segments are considered separate if they are 0.3 inch from other segments. The Dead class is assigned to plants which do not produce leaves.

Recent or decomposed suffixes are assigned to Hollow Center, Clump Edge and Dead form classes. The recent suffix (R) is assigned if old leaf structure is evident on the dead portion of a bunchgrass clump. The decomposed suffix (D) is assigned if old leaf structure is not evident.

12. Units of measurement.

Lengths and widths of bunchgrass clumps and maximum leaf heights are measured to the nearest 0.1 inch. Form classes are assigned.

13. Procedures of measurement.

Two opposed length and width measurements are made through the basal portion of each Normal and Hollow Center plant and the largest segment of each Clump Edge plant. Maximum leaf heights are measured by placing a rule vertically within a bunchgrass clump or segment. Form classes are assigned by observation.

14. Time required to lay out and measure a plot.

Two men are able to lay out a plot in 15 to 20 minutes. With one man recording and another measuring, approximately one and one-quarter to one and one-half hours are required to obtain the various measurements from 100 plants.

GRASS VIGOR MEASUREMENT FORM

District _____ Area _____ Date _____ Key Sp. _____ Plot No. _____

Type _____ Location _____ Examiners _____

Form Classes

N = Normal CE = Clump Edge*
 S = Seedling D = Dead*
 HC = Hollow Center*

Dot Tally

Seedlings _____

Dead $\frac{R}{D}$ _____

*Add recent (R) or decomposed (D) suffixes

Plant No.	No. Steps	Form Class	Basal Area Index			$(LxW)^2$	Max. Leaf Ht.	$(\text{Leaf Ht.})^2$
			Length	Width	LxW			
1	5							
2	4							
3	3							
4	5							
5	2							
6	7							
7	5							
8	3							
9	4							
10	6							
11	5							
12	3							
13	7							
14	6							
15	5							
16	1							
17	2							
18	1							
19	6							
20	5							
21	7							
22	5							
23	2							
24	6							
25	3							
26	4							
27	4							
28	1							
29	6							
30	6							
31	1							
32	1							
33	7							
34	2							
35	4							
36	3							
37	7							
38	6							
39	6							
40	7							
41	5							
42	7							
43	4							
44	4							
45	3							

Figure 2. Field form for recording measurements.

GRASS VIGOR MEASUREMENT FORM

Plot No. _____

Date _____

Plant No.	No. Steps	Form Class	Basal Area Index			$(L \times W)^2$	Max. Leaf Ht.	$(\text{Leaf Ht.})^2$
			Length	Width	LxW			
46	6							
47	3							
48	7							
49	7							
50	4							
51	1							
52	5							
53	4							
54	1							
55	6							
56	1							
57	4							
58	4							
59	5							
60	2							
61	5							
62	3							
63	2							
64	7							
65	2							
66	1							
67	7							
68	7							
69	1							
70	5							
71	5							
72	5							
73	2							
74	2							
75	1							
76	5							
77	6							
78	3							
79	3							
80	2							
81	4							
82	5							
83	3							
84	6							
85	5							
86	2							
87	1							
88	5							
89	1							
90	4							
91	1							
92	1							
93	2							
94	6							
95	6							
96	4							
97	1							
98	7							
99	6							
100	7							

Figure 2 . continued

FIGURE 3 BUNCH GRASS FORM CLASSES

- A. Normal
- B. Hollow Center
- C. Clump Edge

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15. Compilation of data.

Data from one plot or groups of plots may be compiled.

Individual form classes are totaled, discounting those circled (selected as alternatives to the Seedling or Dead Classes). Results are expressed as percentages.

Length and width values for each Normal, Hollow Center and Clump Edge plant are multiplied to give a basal area index. The basal area index and leaf height values for these plants are totaled. Results are expressed as means plus or minus their standard errors.

Means and standard errors are computed by calculating:

$$\bar{Y} = \frac{\sum Y}{n} \quad \text{and} \quad S_{\bar{Y}} = \sqrt{\frac{S^2}{n}}$$

where

$\bar{Y}$ = the mean of basal area or leaf height values

Y = the individual basal area or leaf height values

n = the number of plants measured

$S_{\bar{Y}}$ = the standard error of the basal area or leaf height means

S^2 = the sample variance

The sample variance (S^2), where the data are from one plot, is calculated from the formula

$$S^2 = \frac{\sum Y^2 - \frac{(\sum Y)^2}{n}}{n-1}$$

Where the data are from groups of plots, the pooled estimate of variance is given by

$$S^2 = \frac{(n_1 - 1)S_1^2 \dots (n_g - 1)S_g^2}{(n_1 - 1) \dots (n_g - 1)}$$

where

S_i^2 = the sample variance of the i th plot ($i = 1, 2, \dots, g$)

n_i = the number of plants measured in the i th plot ($i = 1, 2, \dots, g$)

16. Reliability standards for form class percentages.

Confidence limits are used to indicate the reliability of form class percentages. In determining confidence limits consult table 1 in the appendix where

P = the percentage of a class

L_1 = the lower 95 per cent confidence limit

L_2 = the upper 95 per cent confidence limit

n = the sample size

Results are expressed as P ($L_1 - L_2$)

Example: A group of ten plots had 1,000 plants classified as follows:

Class	No. Plants	P	L_1	L_2	Expression
Normal	600	60	57	63	60% (57 - 63)
Seedling	100	10	8	12	10% (8 - 12)
Hollow Center - R	125	13	11	15	13% (11 - 15)
Hollow Center - D	25	3	2	4	3% (2 - 4)
Clump Edge - R	120	12	11	15	12% (10 - 14)
Clump Edge - D	10	1	2	4	1% (0 - 2)
Dead - R	20	2	0	0	2% (1 - 3)
Dead - D	0	0	0	0	0% (0 - 0)

Where sample sizes are other than those shown in table 1 approximate L values for P may be interpolated.

Example: n = 400, P = 50

In table 1, n and L values on either side of n = 400 are:

n	L_1	L_2
1000	47	53
250	44	56

Differences between the n and L values are 750 and 3 respectively. The difference between n = 1000 and n = 400 is 600. Therefore,

$$\frac{600}{750} \times 3 = 2.4 \text{ or } 2$$

and 47-2 (45) and 53+2 (55) express the L_1 and L_2 values where n = 400 and P = 50.

17. Reliability standards for means.

Standard errors (see 15) are used to indicate the reliability of basal area and leaf height means. Standard errors of a basal area mean should be 10 per cent or less of the mean, of a leaf height mean, 5 per cent or less of the mean.

18. Procedure for calculating additional numbers of plants needed to satisfy reliability standards.

When standard error percentages indicate that means are not sufficiently reliable, the number of additional plants needed to give the desired reliability is calculated by the formula

$$N = \frac{S^2}{\frac{S^2}{\bar{Y}}} - n$$

where

N = the numbers of additional plants needed

n = the number of plants measured

S^2 = the sample variance (see 15)

$\frac{S}{\bar{Y}}$ = the desired standard error

Example: Measurements from 100 plants gave a basal area mean of 0.96 inches and a standard error of 0.11 inches. This standard error is about 11 per cent of the mean. A standard error of 0.10 inches (10 per cent of 0.96) is desired. The variance (S^2) of the sample was 1.3. These values are inserted in the formula as follows:

$$N = \frac{1.3}{(0.10)^2} - 100 = 30$$

Therefore, 30 additional plants must be measured to give the desired reliability. In subsequent sampling on the plot, the range of random steps is reduced from one to seven to one to six to permit the selection of thirty additional plants.

19. Procedure for comparing initial and subsequent form class percentages.

Initial and subsequent form class percentages are hypothesized to be similar. A chi-square value is calculated using the formula

$$\chi^2 = \frac{(O - E)^2}{E}$$

where

χ^2 = the chi-square value

O = the observed value

E = the expected value

and the summation extends over all classes.

The calculated chi-square is compared with chi-square values in the proper degrees of freedom (d.f.) row in table 2, Appendix. If the calculated chi-square exceeds the table chi-square in the α column (in the proper d.f. row) the hypothesis is rejected at the 100 α per cent significance level.

Example: Initial (1956) and subsequent (1957) form class percentages were as shown below.

Year	Form Class Percentages								Totals
	Normal	Seedling	Hollow Center		Clump Edge		Dead		
			R	D	R	D	R	D	
1956	60	10	13	3	11	1	1	1	100
1957	40	8	22	5	15	4	4	2	100
Totals	100	18	35	8	26	5	5	3	200

The observed 1956 and 1957 percentages are hypothesized to be similar. The expected value (E) in any cell is calculated as follows:

$$E = (\text{row total} \times \text{column total}) \div (\text{grand total})$$

For example the expected value for Normal 1956 is $(100 \times 100) \div (200) = 50$, Normal 1957 is the same, Seedling 1956 is $(100 \times 18) \div (200) = 9$, etc. Thus:

$$\begin{aligned} \chi^2 = & \frac{(60-50)^2}{50} + \frac{(40-50)^2}{50} + \frac{(10-9)^2}{9} + \frac{(8-9)^2}{9} + \frac{(13-17.5)^2}{17.5} + \\ & \frac{(22-17.5)^2}{17.5} + \frac{(3-4)^2}{4} + \frac{(5-4)^2}{4} + \frac{(11-13)^2}{13} + \frac{(15-13)^2}{13} + \\ & \frac{(1-2.5)^2}{2.5} + \frac{(4-2.5)^2}{2.5} + \frac{(1-2.5)^2}{2.5} + \frac{(4-2.5)^2}{2.5} + \frac{(1-1.5)^2}{1.5} + \\ & \frac{(2-1.5)^2}{1.5} = 11.60 \end{aligned}$$

Looking in table 2, appendix, in the 7 d.f. row $[(\text{No. years} - 1) \times (\text{no. classes} - 1) = (2-1) \times (8-1)]$ our calculated chi-square is seen to exceed the table chi-square value in the .20 α column. Thus the hypothesis of similarity is rejected at the 20 per cent significance level.

20. Procedure for comparing initial and subsequent basal area and leaf height means.

Initial and subsequent means (or any two means) are hypothesized to be similar. A t-value is calculated using the formula

$$t = \frac{\bar{Y}_1 - \bar{Y}_2}{S \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where

$\bar{Y}_1$ = the initial mean

$\bar{Y}_2$ = the subsequent mean

and

$$S = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{(n_1 - 1) + (n_2 - 1)}}$$

If the calculated t-value is outside a plus or minus range of a t-value (table 3, appendix) in an $n_1 + n_2 - 2$ degrees of freedom (d.f.) row and a chosen significance level (α) column, the hypothesis of similarity is rejected. If the calculated t-value falls within the range of plus or minus the t-value, the hypothesis cannot be rejected.

Example: The initial and subsequent means for basal areas where 100 plants were measured each year were 0.82 and 0.61 inches respectively. The pooled standard deviation (S) was 0.7.

The means are hypothesized to be similar. Using the formula

$$t = \frac{.82 - .61}{0.7 \sqrt{\frac{1}{100} + \frac{1}{100}}} = 2.14$$

Choosing a one per cent significance level, we observe that 2.14 is within the critical range of plus or minus t in the 0.01 α column and the $100 + 100 - 2$ (200) d.f. row (table 3, appendix). This t-value is 2.60. Since 2.14 is within this range, we are unable to reject the hypothesis at the one per cent significance level. We note, however, that 2.14 is outside of the range for t in the .05 α column which is -1.97 to +1.97. Therefore, we are able to reject the hypothesis of similarity at the five per cent significance level.

21. Analysis of data.

Trend interpretations from form class percentages depend upon comparisons of initial and subsequent percentages. The degree of confidence in an interpretation is expressed by a significance level at which hypothesis of similarity is, or is not, rejected.

Hollow Center, Clump Edge and Dead form classes are considered to represent stages of deteriorated plant vigor. The suffixes, "R" and "D" are assigned to indicate whether deterioration has resulted from recent or past overuse. Interpretations relative to differences in the Seedling class percentages cannot be made at this writing. The class is considered separately to isolate extremely small basal area measurements which may or may not be influenced by grazing.

Trend interpretations from basal area or leaf height measurements depend upon comparisons of initial and subsequent means. The degree of confidence in an interpretation is expressed by a significance level at which a hypothesis of similarity in means is, or is not, rejected. The basal area index and maximum leaf height measurements are considered to reflect plant vigor.

22. Possible extensions in the method.

On ranges grazed during the summer the method may be used as described with the exception that key bunchgrass leaf heights are not measured.

Where time is a factor, measurement procedures could be simplified to the extent that only the bunchgrass form classes were used. This simplified approach could be used with any acceptable sampling procedure on ranges grazed during any season. In its simplest form an established course could be walked through the area to be sampled. Form classes would be assigned to key bunchgrass plants closest to the toe after completing a specified number of steps.

Key forage grasses on certain ranges may be single stalked species or species which do not grow in compact bunches. Some of these grasses, of possible importance on Montana elk ranges, are western wheatgrass (Agropyron smithii), timber oatgrass (Dathonia unispicata), plains mulley (Mulenburgia cuspidata) and needle-and-thread (Stipa comata). Findings by various authors indicate that measurements of either maximum plant heights or maximum leaf heights will reflect the vigor of these grasses.

An index of key forage grass density may be obtained by measuring the distance between the toe and each of the plants selected by the sampling procedure.

Table 1 -- 95 Per Cent Confidence Intervals.¹

N =	100		250		1000	
	L ₁	L ₂	L ₁	L ₂	L ₁	L ₂
0	0	4	0	1	0	0
1	0	5	0	4	0	2
2	0	7	1	5	1	3
3	1	8	1	6	2	4
4	1	10	2	7	3	5
5	2	11	3	9	4	7
6	2	12	3	10	5	8
7	3	14	4	11	6	9
8	4	15	5	12	6	10
9	4	16	6	13	7	11
10	5	18	7	14	8	12
11	5	19	7	16	9	13
12	6	20	8	17	10	14
13	7	21	9	18	11	15
14	8	22	10	19	12	16
15	9	24	10	20	13	17
16	9	25	11	21	14	18
17	10	26	12	22	15	19
18	11	27	13	23	16	21
19	12	28	14	24	17	22
20	13	29	15	26	18	23
21	14	30	16	27	19	24
22	14	31	17	28	19	25
23	15	32	18	29	20	26
24	16	33	19	30	21	27
25	17	35	20	31	22	28
26	18	36	20	32	23	29
27	19	37	21	33	24	30
28	19	38	22	34	25	31
29	20	39	23	35	26	32
30	21	40	24	36	27	33
31	22	41	25	37	28	34
32	23	42	26	38	29	35
33	24	43	27	39	30	36
34	25	44	28	40	31	37
35	26	45	29	41	32	38
36	27	46	30	42	33	39
37	28	47	31	43	34	40
38	28	48	32	44	35	41
39	29	49	33	45	36	42
40	30	50	34	46	37	43
41	31	51	35	47	38	44
42	32	52	36	48	39	45
43	33	53	37	49	40	46
44	34	54	38	50	41	47
45	35	55	39	51	42	48
46	36	56	40	52	43	49
47	37	57	41	53	44	50
48	38	58	42	54	45	51
49	39	59	43	55	46	52
50	40	60	44	56	47	53

*If P exceeds 50, read 100 - P and subtract each confidence limit from 100.

¹Portion of Confidence Intervals for the Binomial table from Snedecor 1946, p.4.

Appendix

Table 2. Table of χ^2 values.¹

d.f.	α						
	0.50	0.40	0.30	0.20	0.10	0.05	0.01
1	.455	.708	1.07	1.64	2.71	3.84	6.63
2	1.39	1.83	2.41	3.22	4.61	5.99	9.21
3	2.37	2.95	3.67	4.64	6.25	7.81	11.3
4	3.36	4.04	4.88	5.99	7.78	9.49	13.3
5	4.35	5.13	6.06	7.29	9.24	11.1	15.1
6	5.35	6.21	7.23	8.56	10.6	12.6	16.8
7	6.35	7.28	8.38	9.80	12.0	14.1	18.5
8	7.34	8.35	9.52	11.0	13.4	15.5	20.1
9	8.34	9.41	10.7	12.2	14.7	16.9	21.7
10	9.34	10.5	11.8	13.4	16.0	18.3	23.2

¹Portion of Percentage Points of the χ^2 Distribution Table.
Ostle 1954, p.447, by permission of the author.

Table 3. Table of t-values.¹

d.f.	α			
	0.20	0.10	0.05	0.01
100	1.290	1.661	1.984	2.626
200	1.286	1.653	1.972	2.601
300	1.285	1.650	1.968	2.592
400	1.284	1.649	1.966	2.588
500	1.284	1.648	1.965	2.586
1000	1.283	1.647	1.962	2.581

¹Portion of a Percentage Points of the t -
Distribution Table. Ostle 1954, p.451, by
permission of the author.

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