RANGELAND STATISTICS

INTRODUCTION

Statistical tests are an important part of Forest Service data collection and analysis. Managers and line officers need assurances that data provided to them is accurate and valid. This does not imply that all data and information collected by the agency can be statistically defensible. There is simply not sufficient funding, nor is it necessary to collect all information in this manner. Prior to inventory or monitoring activities, managers should decide what level of reliability they want for their study and then design the sampling methods to achieve that level of reliability.

This appendix[1] is intended as a practical approach for rangeland management personnel to identify the intensity of information needed to complete accurate inventory and monitoring assignments in a statistically reliable manner. This information can best be presented by grouping statistical requirements into three categories:

1. Determine the number of transects and the number of plot frames per transect required to adequately sample the variability of the site.
2. Estimate the sample mean and determine the variability of the mean through coefficients of variation and confidence intervals.
3. Determine whether a "significant change" has occurred between two points in time through remeasurement of a permanent monitoring plot.

The process for evaluating each of these categories is described in this appendix.

DETERMINE NUMBER OF TRANSECTS AND PLOT FRAMES

Field examiners should determine the number of transects and the number of plot frames per transect required to adequately sample the variability of the site.

[1] Compiled by Michele Girard, Forest Ecologist, Bighorn National Forest, Sheridan, Wyoming.

NUMBER OF TRANSECTS

A minimum number of transects is established for all methods in the guide. Cover-frequency and line intercept methods require a minimum of two transects per site for inventory and three transects for monitoring. Rooted nested frequency method requires a minimum of five transects. The examiner must determine when additional transects are needed.

This is accomplished by keeping track of the (a) cumulative number of plant species encountered on the transect, (b) the absolute number of new plant species encountered with each additional transect, and (c) the percent increase of new plant species for each transect. Percent increase in new plant species is calculated by dividing the absolute number of new species on a transect by the cumulative number of species encountered up to, and including, that transect. When the increase in new plant species recorded is less then 25 percent for two consecutive transects, no additional transects are required.

Table C- 1 and Table C- 2 illustrate the percent increase in new plant species for two different sites. The example in Table C- 1is for a site (A) where five transects sufficiently sampled the variability. In fact, four transects are sufficient in this example. The example in Table C- 2 is for a site (B) where two additional transects are needed.

SPECIES-AREA CURVES

An alternative method of determining the number of transects to sample is through the construction of a species-area curve from the data as shown in Figure C- 1. When the slope of a species-area curve flattens out, no additional transects are needed. When permanent plots are remeasured, the number of transects must be remain constant.

NUMBER OF PLOT FRAMES ON A TRANSECT

The minimum number of plot frames on a transect is established for each inventory and monitoring method in this Guide. Each cover-frequency transect must have a minimum of 20 plot frames, and each rooted nested frequency transect must have a minimum of 10 plot frames. To determine whether additional plot frames are needed, follow the same procedure used to determine the number of transects needed.

By tracking the cumulative number of species encountered and the absolute number of new species, the percent increase in new plant species can be calculated. If the percent increase in new species is 25 percent or less for two consecutive plot frames, then no additional frames are needed. A species-area curve can also be used to determine the number of plot frames needed. When permanent plots are remeasured, the number of plot frames per transect must remain constant.

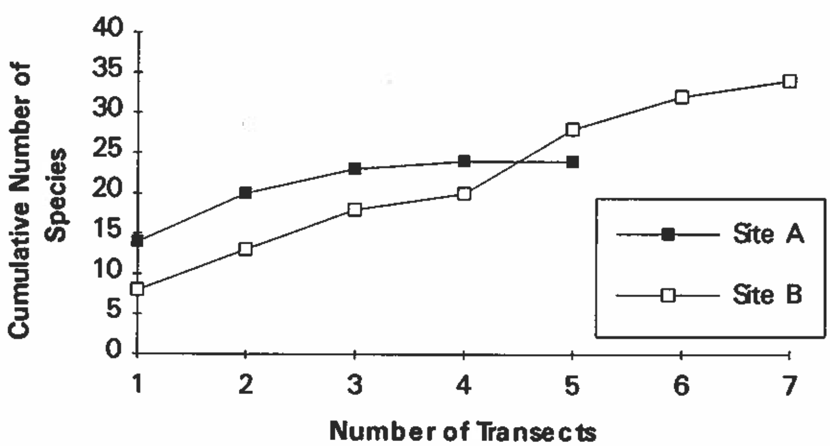
Table C- 1. SAMPLING ADEQUACY: SITE A

Transect Number	Cumulative Number of Species	Absolute Number of New Species	Percent Increase in New Species
1	14	14	100%
2	20	6	30%
3	23	3	13%
4	24	1	4%
5	24	0	0%

Table C- 2. SAMPLING ADEQUACY: SITE B

Transect Number	Cumulative Number of Species	Absolute Number of New Species	Percent Increase in New Species
1	8	8	100%
2	13	5	38%
3	18	5	28%
4	20	2	10%
5	28	8	29%
6	32	4	12%
7	34	2	6%

Figure C- 1. SPECIES-AREA CURVES



DETERMINE DATA VARIABILITY

Evaluation of rangeland inventory data involves the computation of sample means for a diverse set of parameters. The variability of the data must be described in order to accurately interpret the data. Since the true value of a given parameter, usually a sample mean, may not be known, it is necessary to describe the variability of that parameter and to determine the accuracy of that parameter.

The coefficient of variation (CV) describes the amount of variability in a population. In addition, confidence intervals (CI) can be established for the parameter at different confidence levels. For example,

> "the 80 percent confidence interval for production within a community is between 1,400 and 2,000 pounds."

The procedures outlined in this appendix are from "The Lighter Side of Statistics".[2]

Coefficients of variation and confidence intervals can be computed for all types of data, including cover, density, production, and frequency data.

There is one distinction that must be made, however, if frequency data is evaluated. Frequency data is different from cover, production, and density data because it is binomial data. Frequency data detects a presence or absence, and does not result in a numeric value (such as a percent cover or pounds/acre). However, presence can be equated to one (1) and absence equated to zero (0). The 1's and 0's for each transect can be summed and the appropriate statistical tests applied. *It is important to note that instead of using plot frame data for frequency, transect data must be used.* The requirements for cover, density, and production data versus frequency data are displayed in Table C- 3.

It is critical that this distinction is made before beginning the analysis and that the appropriate sample unit (plot frame or transect) is consistently applied throughout the analysis.

Examples of plot frame based and transect based analyses are presented in this Appendix.

Table C- 3. DATA REQUIREMENTS FOR APPLYING COEFFICIENTS OF VARIATION AND CONFIDENCE INTERVALS

	DATA TYPE	
	cover, density, or production	frequency
SAMPLE UNIT	plot frame	transect
NUMBER OF SAMPLE UNITS	more than 1 plot frame	more than 1 transect
SAMPLE UNIT SIZE	plot frames are of uniform size	—
SAMPLE UNIT PLACEMENT	—	transects are of uniform length
RECORDED INFORMATION	data is recorded by plot frame	data is recorded by plot frame

[2] USDA Bureau of Land Management, 1986.

Coefficient of Variation

Follow the instructions below to complete Form C-1. Do not be overwhelmed by this lengthy list of steps. The instructions are designed to provide an easy step-by-step procedure. Inexpensive hand-held calculators are often already programmed to do many of these calculations. A completed example is included.

1. Select a species (usually a key or dominant species) and complete the Species Block at the top of the form. Identify the attribute sample (production, cover, density, frequency, etc.) in the Attribute Block. Complete the remainder of the header information.
2. Circle the sample unit: plot frame or transect. For non frequency data count the plot frames sampled and enter that number in the space provided. For frequency data count the number of transects sampled and enter that number. This value is the sample size (n).
3. Enter the sampled value for the species selected in the column (X). For example, the percent canopy cover for each plot frame, or the frequency count for each transect. Make an entry for each plot frame, or for each transect.
4. Sum the (X) column and enter the answer at the bottom of the column ($\sum X$).
5. Divide ($\sum X$) by (n) in block 1 at the bottom of the Form. This number is the mean or average ($\overline{X}$) for the species for all plot frames, or for all transects. Fill the spaces in the ($\overline{X}$) column with this value.
6. Subtract the average ($\overline{X}$) from the sampled values (X) for each plot frame, or transect. Enter the difference in the two ($X-\overline{X}$) columns.
7. Multiply one ($X-\overline{X}$) column by the other ($X-\overline{X}$) column; in other words, compute the square of the difference $(X-\overline{X})^2$. Remember a negative times a negative always equals a positive, so $(X-\overline{X})^2$ will always be positive. Enter each product in the $(X-\overline{X})^2$ column.
8. Sum the $(X-\overline{X})^2$ column and enter the answer at the bottom of the column. This is the sum of squares.
9. Divide the sum of squares $\sum(X-\overline{X})^2$ by the degrees of freedom (n-1) — one less than the number of plot frames, or one less than the number of transects — and enter the quotient in the (S^2) spaces. This equation is in block 2. S^2 is the variance of the data.
10. Calculate the square root of the variance (S^2) in block 3 and enter that value in the (S) blanks. (S) is the standard deviation.
11. Divide the standard deviation (S) by the mean ($\overline{X}$) in block 4 and enter this number in the (CV) space. CV is the coefficient of variation for the species.

Confidence Intervals

Confidence intervals are based on a specified level of confidence, the sample size (*n*), and the coefficient of variation. The same example from above is used to illustrate.

1. Turn to the back of Form C-1. Enter the sample average ($\overline{X}$) in the six blocks indicated.
2. Use Graphs C-1 and C-2 to obtain the percent ± the mean for the 90 percent and 80 percent confidence levels, respectively. For most purposes, the 80 percent confidence level will be sufficient. If (*n*) is five or less, consider using the Graphs C-3 and C-4.
3. Locate the appropriate sample size (*n*) on the bottom of the Graphs C-1 and C-2 and the coefficient of variation (CV) on the left-hand side. At the point where these intersect, follow the curve all the way to the right-hand side, staying between the curved lines. The value along the right-hand axis is the precision of the mean, expressed in terms of a percentage above and below the mean. Enter these values into the appropriate blocks. Maintain the distinction between the 90 percent and 80 percent confidence level rows.
4. Do the subtraction and addition of the percentages first, before multiplying by the sample average ($\overline{X}$). Enter the products of these computations in the shaded blocks labeled lower and upper limit. These values bracket the confidence interval, at the respective confidence levels, for the average ($\overline{X}$).

Examples

In the first example, the sample size (*n*) is 20 plot frames and the coefficient of variation (CV) is 0.74. Using these values and Graphs C-1 and C-2, the 90 percent confidence limit is ± 28 percent and the 80 percent confidence limit is ± 22 percent.

This means you can be 90 percent confident that the average canopy cover of FEID is within ± 28 percent of the actual mean and 80 percent confident that the average canopy cover of FEID is within ± 22 percent of the actual mean. Therefore, the respective confidence intervals are:

$10.9 \leq 15.1 \leq 19.3$ @90 percent

$11.8 \leq 15.1 \leq 18.4$ @80 percent

In the second example, the sample size (*n*) is 5 transects and the coefficient of variation (CV) is 0.18. Using these values and Graphs C-3 and C-4, the 90 percent confidence limit is ± 17 percent and the 80 percent confidence limit is ± 12 percent.

This means you can be 90 percent confident that the average frequency of FEID is within ± 17 percent of the actual mean and 80 percent confident that the average frequency of FEID is within ± 12 percent of the actual mean. Therefore, the respective confidence intervals are:

$10.0 \leq 12.0 \leq 14.0$ @90 percent

$10.6 \leq 12.0 \leq 13.4$ @80 percent

Form C-1
COMPUTATION OF COEFFICIENT OF VARIATION AND CONFIDENCE INTERVALS

State	Wyoming	Species	FEID
District	Wind River	Attribute	Canopy Cover
Allotment	Black Mesa	Date	8/14/93
Study	2	# of **Plot Frames** or Transects	20 (n)

	X		$\overline{X}$		$X-\overline{X}$		$X-\overline{X}$		$(X-\overline{X})^2$
1	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
2	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
3	2.0	-	15.1	=	-13.1	x	-13.1	=	172
4	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
5	2.0	-	15.1	=	-13.1	x	-13.1	=	172
6	37.5	-	15.1	=	22.4	x	22.4	=	502
7	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
8	2.0	-	15.1	=	-13.1	x	-13.1	=	172
9	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
10	37.5	-	15.1	=	22.4	x	22.4	=	502
11	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
12	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
13	37.5	-	15.1	=	22.4	x	22.4	=	502
14	2.0	-	15.1	=	-13.1	x	-13.1	=	172
15	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
16	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
17	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
18	2.0	-	15.1	=	-13.1	x	-13.1	=	172
19	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
20	15.0	-	15.1	=	-0.1	x	-0.1	=	0.01
ΣX	302.5							$\Sigma(X-\overline{X})^2$	2366

1. $\overline{X} = \dfrac{\sum_{i=1}^{n} X_i}{n}$ $\quad \overline{X} = \dfrac{302.5}{20} = 15.1$

2. $S^2 = \dfrac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1}$ $\quad S^2 = \dfrac{2366}{19} = 125$

3. $S = \sqrt{S^2}$ $\quad S = \sqrt{125} = 11.2$

4. $CV = \dfrac{S}{\overline{X}}$ $\quad CV = \dfrac{11.2}{15.1} = .74$

CONFIDENCE INTERVALS

From Graphs C-1, C-2, C-3, or C-4 complete the blanks for the percentage ± the mean for 90 percent and 80 percent confidence levels. Use the sample size (*n*) and the Coefficient of Variation (CV). The shaded blocks represent the lower and upper limits of the confidence interval surrounding $\overline{X}$, where $\overline{X}$ is the mean density, cover, or production value, or the mean frequency value.

Confidence Level		% ± mean		$\overline{X}$		Lower Limit		$\overline{X}$			% ± mean		$\overline{X}$		Upper Limit
90%	(100% -	28	)x	15.1	=	10.9	≤	15.1	≤	(100% +	28	)x	15.1	=	19.3
80%	(100% -	22	)x	15.1	=	11.8	≤	15.1	≤	(100% +	22	)x	15.1	=	18.4

Form C-1
COMPUTATION OF COEFFICIENT OF VARIATION AND CONFIDENCE INTERVALS

State	Wyoming	Species	FEID
District	Wind River	Attribute	Frequency
Allotment	Black Mesa	Date	8/25/93
Study	3	# of Plot Frames or <u>Transects</u>	5 (20 frames/transect) (n)

	X		$\overline{X}$		$X-\overline{X}$		$X-\overline{X}$		$(X-\overline{X})^2$
1	11	-	12.0	=	-1	x	-1	=	1
2	15	-	12.0	=	3	x	3	=	9
3	12	-	12.0	=	0	x	0	=	0
4	9	-	12.0	=	-3	x	-3	=	9
5	13	-	12.0	=	1	x	1	=	1
6		-		=		x		=	
7		-		=		x		=	
8		-		=		x		=	
9		-		=		x		=	
10		-		=		x		=	
11		-		=		x		=	
12		-		=		x		=	
13		-		=		x		=	
14		-		=		x		=	
15		-		=		x		=	
16		-		=		x		=	
17		-		=		x		=	
18		-		=		x		=	
19		-		=		x		=	
20		-		=		x		=	
ΣX	60							$\Sigma(X-\overline{X})^2$	20

1. $\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$ $\qquad \overline{X} = \frac{60}{5} = 12.0$

2. $S^2 = \frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1}$ $\qquad S^2 = \frac{20}{4} = 5.0$

3. $S = \sqrt{S^2}$ $\qquad S = \sqrt{5} = 2.2$

4. $CV = \frac{S}{\overline{X}}$ $\qquad CV = \frac{2.2}{12.0} = 0.18$

CONFIDENCE INTERVALS

From Graphs C-1, C-2, C-3, or C-4 complete the blanks for the percentage ± the mean for 90 percent and 80 percent confidence levels. Use the sample size (*n*) and the Coefficient of Variation (CV). The shaded blocks represent the lower and upper limits of the confidence interval surrounding $\overline{X}$, where $\overline{X}$ is the mean density, cover, or production value, or the mean frequency value.

Confidence Level		% ± mean		$\overline{X}$		Lower Limit		$\overline{X}$		% ± mean		$\overline{X}$		Upper Limit
90%	(100% -	17	)x	12	=	10.0	≤	12	≤ (100% +	17	)x	12	=	14.0
80%	(100% -	12	)x	12	=	10.6	≤	12	≤ (100% +	12	)x	12	=	13.4

Number of Samples

It is possible to easily determine whether the sample size is adequate while still in the field.

1. Determine the confidence level desired: either 80 percent or 90 percent.
2. Do the calculations described above to determine the coefficient of variation (CV) for the data (steps 1-11).
3. Use Graph C-2 for the 80 percent confidence level (or Graph C-1 for 90 percent) to determine the confidence limit for the mean.
4. If the confidence limit is ± 20 percent or less for an 80 percent confidence level (or ± 10 percent or less for a 90 percent confidence level) then the sample size is adequate. If the confidence limit is greater than 20 percent, or 10 percent, respectively, then proceed to the next step.
5. Go to the right-hand axis of Graph C-2, find the 20 percent mark for the 80 percent confidence level (or 10 percent mark for the 90 percent confidence level), and follow the curved line until it intersects the coefficient of variation (CV) value computed in step 2. Follow this line straight down to the sample size (*n*) value. That value is the number of samples required to achieve the desired confidence level.

In the first example, the confidence limit is 16 percent for the 80 percent confidence level. This is an adequate sample size for that confidence level. However, the confidence limit of 21 percent for the 90 percent confidence level is too high. From the shape of the curves in Graph C-1, it can be determined that a considerably larger sample size (*n*) than 20 will be needed to adequately describe the variability of the data.

DETERMINE IF A SIGNIFICANT CHANGE HAS OCCURRED

Perhaps the most important aspect of making rangeland management decisions is determining whether a "significant change" in species composition (cover), production, or frequency has occurred over time. By using the term "significant change," a statistically significant difference in the data collected at two different times on the same site must be shown.

There are certain requirements that must be followed in order to determine if these statistical analyses can be done on the data:

1. All data must be collected using the same sampling techniques each time: the same plot frame size, the same transect length and location, the same method to estimate canopy cover, etc.
2. Data analysis must use the same procedures each time.

The Rocky Mountain Region has opted to use a statistical t-test to determine if there have been significant changes in the data through time. The numbers needed for the t-test are the same as those calculated for confidence intervals. Refer to Form C-1 for these values and enter them on Form C-2. These calculations will show the amount that individual species has changed.

1. Fill in the blanks for year, sample size (n_1 and n_2), sample average ($\overline{X}_1$ and $\overline{X}_2$), and sample variance (S_1^2 and S_2^2) for times 1 and 2 (from Form C-1). Notice that a subscript has been added in order to distinguish data from different times, 1 for the first point in time and 2 for the second.

2. Use the equation in line 1 on Form C-2 to compute the variance (S^2). This is a new value for (S^2) which is the average of the variance from each year (S_1^2) and (S_2^2) and weighted by the number of samples from each year ($n_1 - 1$) and ($n_2 -$).

3. Use the equation in line 2 on Form C-2 to compute the variance of the difference between the two times (S_d^2).

4. Use the equation in line 3 on Form C-2 to compute the square root of the variance of the difference (S_d^2) The result is the standard deviation of the difference (S_d).

5. Use the equation in line 4 on Form C-2 to determine the combined degrees of freedom (df). In order to use each transect as a sample (or a value for *n*), each transect must be randomly located. Otherwise, the entire plot is only one sample and there is only one degree of freedom.

6. Look up the t-test value in Table C-4 using the degrees of freedom (df) from step 5. Fill in the blanks in line 5a with these t-test values.

7. Multiply the standard deviation of the difference (S_d) from step 4 by each of the t-test values in line 5a and put these values in line 5b.

8. Compute the difference between $\overline{X}_1$ and $\overline{X}_2$. Subtract the smaller from the larger number so that the difference is positive.

9. Compare the difference from line 6 to the values in line 5b. If the difference exceeds a value in line 5b, then you are that percent confident (depending on which column meets the criteria) that a change has occurred. Select the largest value in line 5b that the difference exceeds, and thus the corresponding confidence will be as high as possible.

Form C-2
DETERMINE SIGNIFICANT CHANGE

	$Time_1$	$Time_2$
Year	**1983**	**1993**
Number of Samples (n)	**20**	**20**
Mean or Average ($\overline{X}$)	**10.3**	**15.1**
Variance (S^2)	**86**	**125**

1. $$\frac{[(n_1-1)S_1^2+(n_2-1)S_2^2}{(n_1-n_2-2)}=S^2$$ $$S^2=\frac{19\times 86+19\times 125}{20+20-2}=\frac{4009}{38}=105.5$$

2. $$\frac{S^2}{n_1}+\frac{S^2}{n_2}=S_d^2$$ $$S_d^2=\frac{105.5}{20}+\frac{105.5}{20}=10.55$$

3. $$\sqrt{S_d^2}=S_d$$ $$S_d=3.25$$

4. $$n_1+n_2-2=\text{df}$$ $$\text{df}=20+20-2=38$$

5. t-test value from Table C-4

Confidence Level	70%	80%	90%	95%
a. t-test value	1.05	1.30	1.68	2.02
b. S_d x t-test	3.41	4.22	5.46	6.56

6. $$\left|\overline{X}_1-\overline{X}_2\right|=\text{diff}$$ $$\text{diff}=4.80$$

(Difference must be ≥ 0)

CONCLUSION: *We are 80 percent confident that a significant change has occured in canopy cover of FEID in the past 10 years.*

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Form C-1
COMPUTATION OF COEFFICIENT OF VARIATION AND CONFIDENCE INTERVALS

State		Species	
District		Attribute	
Allotment		Date	
Study		# of **Plot Frames** or Transects	(*n*)

	X		$\bar{X}$		$X-\bar{X}$		$X-\bar{X}$		$(X-\bar{X})^2$
1		-		=		x		=	
2		-		=		x		=	
3		-		=		x		=	
4		-		=		x		=	
5		-		=		x		=	
6		-		=		x		=	
7		-		=		x		=	
8		-		=		x		=	
9		-		=		x		=	
10		-		=		x		=	
11		-		=		x		=	
12		-		=		x		=	
13		-		=		x		=	
14		-		=		x		=	
15		-		=		x		=	
16		-		=		x		=	
17		-		=		x		=	
18		-		=		x		=	
19		-		=		x		=	
20		-		=		x		=	
ΣX								$\Sigma(X-\bar{X})^2$	

1. $\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$ $\bar{X} = \frac{\_\_\_}{\_\_\_} = \_\_\_\_\_$	2. $S^2 = \frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1}$ $S^2 = \frac{\_\_\_}{\_\_\_} = \_\_\_\_\_$
3. $S = \sqrt{S^2}$ $S = \sqrt{\_\_\_\_\_} = \_\_\_\_\_$	4. $CV = \frac{S}{\bar{X}}$ $CV = \frac{\_\_\_}{\_\_\_} = \_\_\_\_\_$

CONFIDENCE INTERVALS

From Graphs C-1, C-2, C-3, or C-4 complete the blanks for the percentage ± the mean for 90 percent and 80 percent confidence levels. Use the sample size (*n*) and the Coefficient of Variation (CV). The shaded blocks represent the lower and upper limits of the confidence interval surrounding $\overline{X}$, where $\overline{X}$ is the mean density, cover, or production value, or the mean frequency value.

Confidence Level		% ± mean		$\overline{X}$		Lower Limit		$\overline{X}$		% ± mean		$\overline{X}$		Upper Limit
90%	(100% -		)x		=		≤		≤ (100% +		)x		=	
80%	(100% -		)x		=		≤		≤ (100% +		)x		=	

Form C-2
DETERMINE SIGNIFICANT CHANGE

	$Time_1$	$Time_2$
Year		
Number of Samples (n)		
Mean or Average ($\overline{X}$)		
Variance (S^2)		

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

2. $\frac{S^2}{n_1}+\frac{S^2}{n_2}=S_d^2$ $S_d^2 =$

3. $\sqrt{S_d^2}=S_d$ $S_d =$

4. $n_1+n_2-2=\text{df}$ df =

5. t-test value from Table C-4

Confidence Level	70%	80%	90%	95%
a. t-test value	1.05	1.30	1.68	2.02
b. S_d x t-test	3.41	4.22	5.46	6.56

6. $\left|\overline{X}_1-\overline{X}_2\right|=\text{diff}$ diff =
(Difference must be ≥ 0)

CONCLUSION: ____

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Table C-4
t-test Values

Levels of Confidence

df	70%	80%	90%	95%
1	1.96	3.08	6.31	12.71
2	1.39	1.89	2.92	4.30
3	1.25	1.64	2.35	3.18
4	1.19	1.53	2.13	2.78
5	1.16	1.48	2.02	2.57
6	1.13	1.44	1.94	2.45
7	1.12	1.42	1.90	2.37
8	1.11	1.40	1.86	2.31
9	1.10	1.38	1.83	2.26
10	1.09	1.37	1.81	2.23
11	1.09	1.36	1.80	2.20
12	1.08	1.36	1.78	2.18
13	1.08	1.35	1.77	2.16
14	1.08	1.35	1.76	2.15
15	1.07	1.34	1.75	2.13
16	1.07	1.34	1.75	2.12
17	1.07	1.33	1.74	2.11
18	1.07	1.33	1.73	2.10
19	1.07	1.33	1.73	2.09
20	1.06	1.33	1.73	2.09
21	1.06	1.32	1.72	2.08
22	1.06	1.32	1.72	2.07
23	1.06	1.32	1.71	2.07
24	1.06	1.32	1.71	2.06
25	1.06	1.32	1.71	2.06
26	1.06	1.32	1.71	2.06
27	1.06	1.31	1.70	2.05
28	1.06	1.31	1.70	2.05
29	1.06	1.31	1.70	2.05
30	1.06	1.31	1.70	2.04
40	1.05	1.30	1.68	2.02
60	1.05	1.30	1.67	2.00
120	1.04	1.29	1.66	1.98
∞	1.04	1.28	1.65	1.96

STATISTICAL FORMULAS

n	number of transects (frequency, line cover, point cover) or plots (plot cover, density, production)		
X	species or sample values		
$\overline{X}$	mean or average	formula:	$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$
S^2	sample variance	formula:	$S^2 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}$
S	sample standard deviation	formula:	$S = \sqrt{S^2}$
CV	coefficient of variation	formula	$CV = \frac{S}{\overline{X}}$
E	precision or percentage above and below the mean (NOTE: in statistical calculations decimal equivalents are always used — 0.10 instead of 10%)		
$t_{.90}$	t-test value at the 90 percent confidence level (or 10 percent chance to be wrong), with degrees of freedom equal to (n-1)		
$t_{.95}$	t-test value at the 95 percent confidence level (or 5 percent chance to be wrong)		
$t_{.80}$	t-test value at the 80 percent confidence level (or 20 percent chance to be wrong)		

TO SOLVE FOR:

number (n) of required transect to reach a particular level of confidence and ± a specified percentage of the mean, given t-test, CV, and E

$$n = \frac{\text{t-test}^2 \times CV^2}{E^2}$$

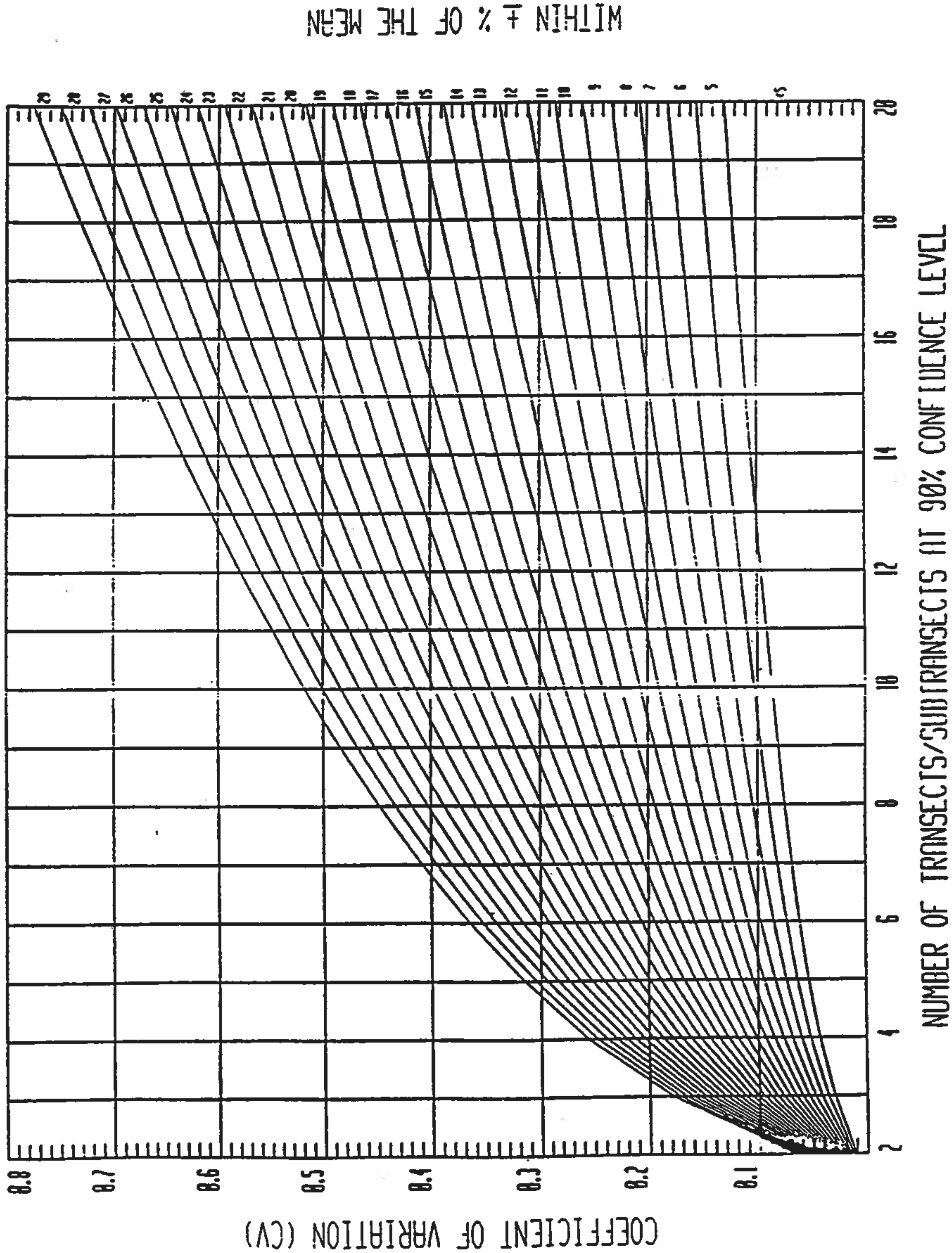
± a specified percentage of the mean (E), given t-test, CV, and n

$$E = \text{t-test} \times CV \times \sqrt{\frac{1}{n}}$$

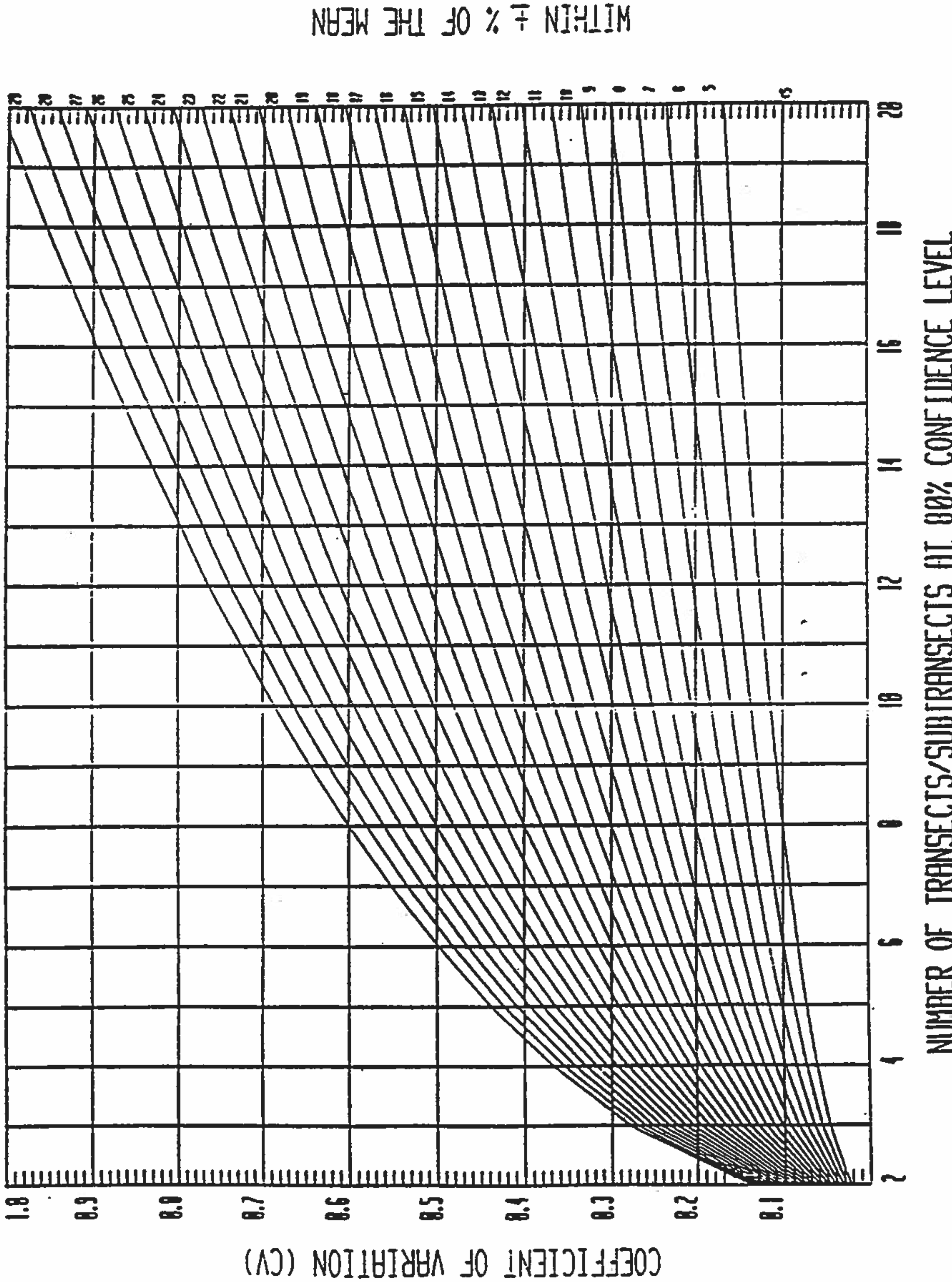
coefficient of variation (CV), given n, E, and t-test

$$CV = \frac{\sqrt{n} \times E}{\text{t-test}}$$

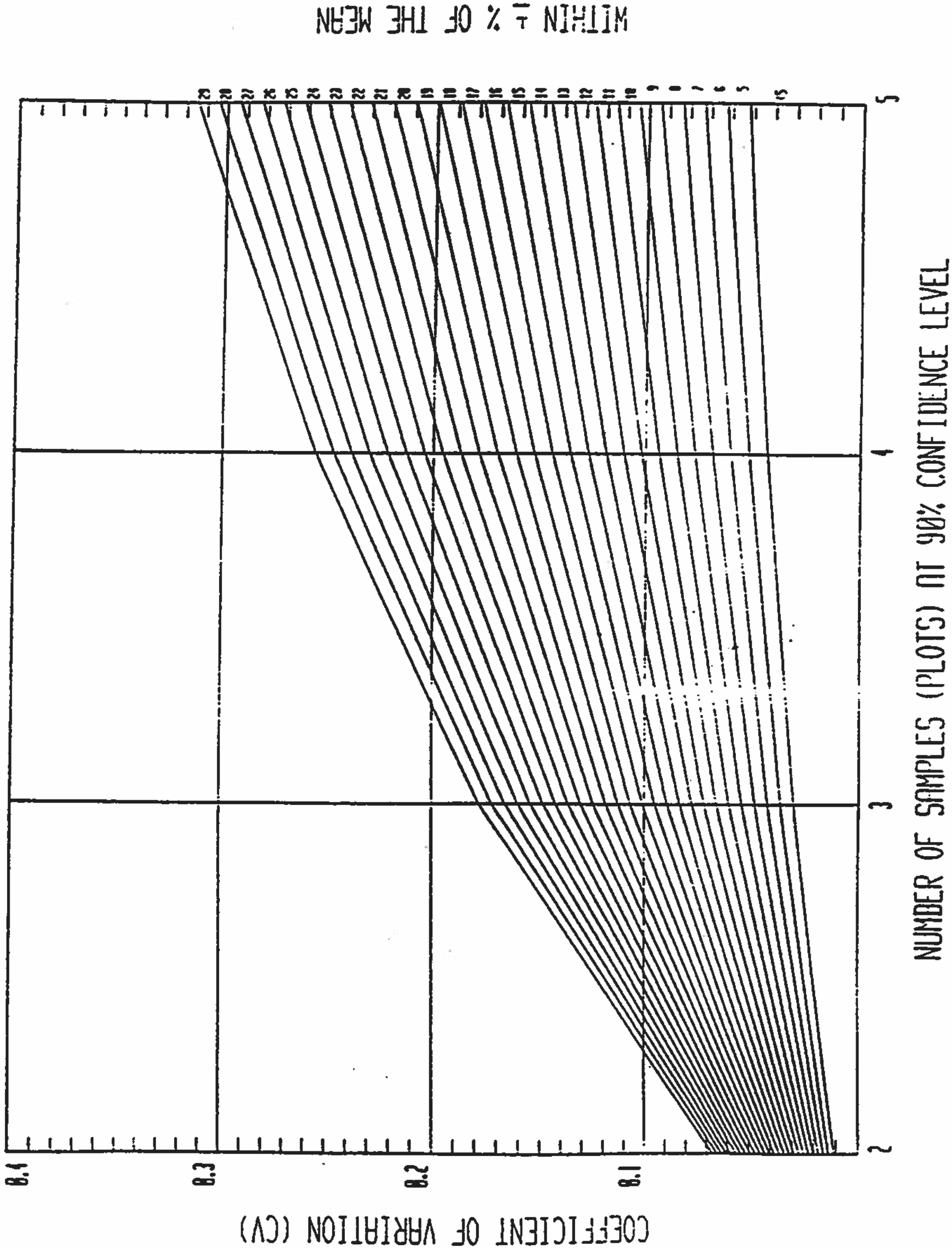
Graph C-1. 90 PERCENT CONFIDENCE LEVEL, $n > 5$



Graph C-2. 80 PERCENT CONFIDENCE LEVEL, *n* > 5



Graph C-3. 90 PERCENT CONFIDENCE LEVEL, $n \leq 5$



Graph C-4. 80 PERCENT CONFIDENCE LEVEL, $n \leq 5$