A Comparison of the Charting, Line Intercept, and Line Point Methods of Sampling Shrub Types of Vegetation[1]

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Nearly all the reported sampling of brush communities presents data on extent of foliage cover. A few results are given in terms of frequency and of numbers of plants and interpreted on a basis of percentage species composition. The data are generally used in the evaluation of condition and trend of brush ranges under the impact of browsing or some type of manipulation. Pressure for more and better hunting of big game is enhancing the value of browse and the need for efficient sampling techniques. At present the investigator who is working on brushland problems must borrow and modify the techniques used by the grassland ecologist and the forester. These modified methods have not undergone extensive tests for accuracy and reliability. In fact reports of quantitative sampling in brush for species composition are scarce in comparison with the data available for grasslands and forests.

The purpose of this study was to compare for accuracy and practicability the techniques of charting, line intercept, and line point in the sampling of two shrub communities. The characteristic of the vegetation that was measured in all three methods was area of the soil covered by the woody plants when their canopies were projected perpendicularly to the soil surface.

One study area was located on the Hopland Field Station in southeastern Mendocino County, California and the other on the Lion Point area of the San Joaquin winter deer range in Madera County.

Related Studies

The first studies on shrubs used square or rectangular plots of varying sizes. The milacre was the most common. On these quardats ocular estimates of cover were made (Forsling and Storm, 1929; van Breda, 1937; Horton, 1941; and Sampson, 1944). In an attempt to reduce the inaccuracies of ocular estimates, Nelson (1930) suggested accurate charting of shrub canopies by a two-man team with the aid of a tape and traverse board. Osborn, Wood, and Paltridge (1935) divided square plots into a grid with strings and charted canopies by measurements from the intersections. Pickford and Stewart (1935) used two parallel steel tapes to mark the boundary of a belt transect. They charted the canopies by measurement of canopies from a metal strip moved between the two tapes. Horton and Kraebel (1955) employed both procedures of ocular estimates and charting. The charting methods are tedious and slow in the field and require considerable amounts of office time. They have not been used extensively for that reason.

Bauer (1936) used the line transect, along which he measured the canopy intercept. In a later paper (1943) he reported an intensive study in which he compared transects and quadrats on a known artificial population. The results indicated that the line intercept was probably more accurate than the quadrat and required less time. The line was much easier to use in woody vegetation than the quadrat. Parker and Savage (1944) included shrubs in their study of the reliability of the line intercept method in measuring the vegetation of the Southern Great Plains. The method was applied effectively in an extensive study of the creosote bush area along the upper Rio Grande Valley (Gardner, 1951) and to study forage conditions on winter game range along the Salmon River in Idaho (Smith, 1954). Hedrick (1951) combined determinations of numbers of plants on milacre plots and intercepts to study succession on chamise areas following brush manipulation.

As early as 1942, Parker and Glendening suggested a line of points along a paced compass line to measure forage utilization in a mixed grass type in the Southwest. A modification of this procedure in which the transects are permanently marked and the point has been enlarged to a 0.75-inch-diameter circle is used to determine condition and trend on national forests (Parker 1951, 1953). The line point method is employed in the study of deer, livestock, forage relationships in California (Dasmann, 1951; Dasmann and Blaisdell, 1954; and Interstate Deer

[1] *The data from the Hopland Field Station were collected as a part of Project 1501 in the California Agricultural Experiment Station. The material from Madera County was from a project conducted cooperatively by the University of California and the California Department of Fish and Game under Federal Aid in Wildlife, Restoration Act Project California W-51R, Big Game Investigations.*

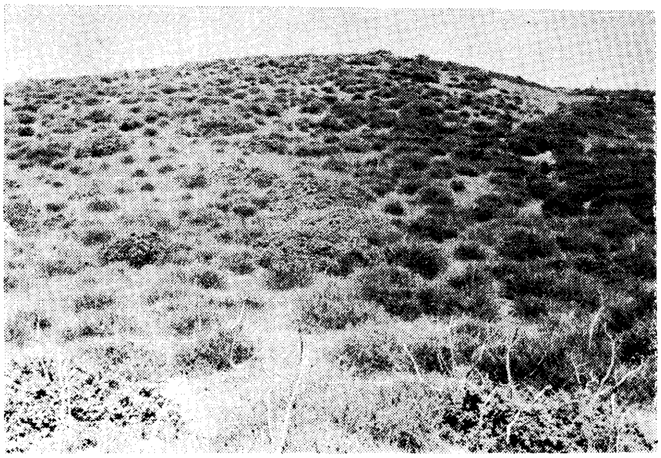

FIGURE 1. Hedged chamise and leather oak on the plot at the Hopland Field Station.

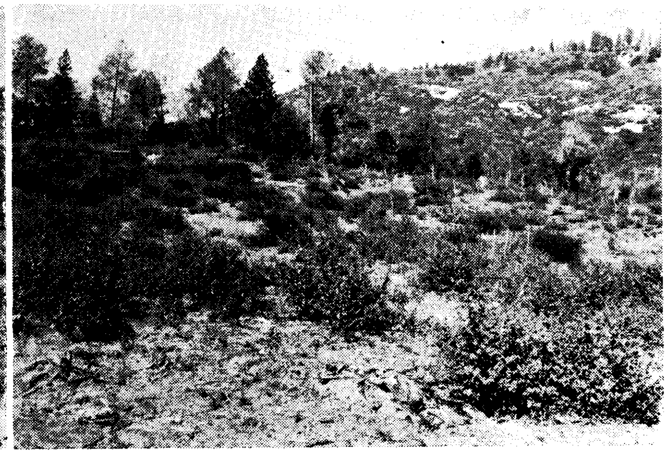

FIGURE 2. Sprouts of flannel bush and liveoak on one of the plots in Madera County.

Herd Committee, 1954).

Taber (1955) used a rope with 3-foot marks instead of a tape to sample heavy mature brush. The rope, with a weight on one end, was thrown across the top of the brush. The observer did not need to follow the transect exactly to read the points. These adaptations of the line point method greatly facilitated sampling in thick brush.

Methods

In the Hopland area a plot of mixed brush 100 feet on a side was selected for study. The first step was to stake the corners. The second step was to map the canopy outlines of all woody plants at a scale of ½ inch on the map to 1 foot on the ground. In those cases where the canopy boundaries were not clear-cut an estimated boundary was drawn which excluded interspaces exceeding 2 inches. This was not considered a serious source of variation before sampling but it may have contributed to some of the variation between species. The third step was to measure the intercept of shrub canopies along 20 lines, each 100 feet in length and located at 10-foot intervals in two directions across the plot. The fourth step was to take point plots at the foot markers along the tape by noting the hit of the point of a plumb bob suspended so that the supporting string touched the tape.

On the San Joaquin area two plots 100 feet on a side were selected in an area where a stand of mixed brush had been mashed and burned the preceding year. After the corners of the plots were established, intercept of shrubby vegetation was measured along 40 lines 100 feet long and spaced at 5-foot intervals across the plot in both directions. Point plots were taken at each foot marker along the same lines. Data for each 5-foot segment of the lines were recorded separately, coded, and punched on IBM cards.

Time to read the field plots and to summarize the field sheets was recorded for part of the work in each area.

Composition of the Vegetation

The general appearance of the Hopland plot is of separate bushes of chamise *(Adenostoma fasciculatum)*, leather oak *(Quercus durata)*, and wedgeleaf ceanothus *(Ceanothus cuneatus)*. Hereafter it will be referred to as the chamise plot. Three other species; redberry *(Rhamnus crocea)*, deer brush *(Ceanothus integerrimus)*, and manzanita *(Arctostaphylos glandulosa)* were present but very scarce. Most of the plants were under 3 feet in height and had been closely hedged by grazing animals (Figure 1). The average length of individual plant intercepts by the line transect method was 2.37 feet for chamise, 3.23 feet for oak, and 1.28 feet for ceanothus. Even though these intercepts do not represent average crown diameters, they do give an approximate picture of relative plant width. The canopies of some plants touched and intermingled so that areas of several square feet had continuous cover.

In terms of ground cover about 35 percent was covered by chamise, 8 percent by oak, and 6 percent by ceanothus. The others contributed less than one percent of the cover. The total cover was slightly over 50 percent. In terms of percentage species composition, chamise was about 70 percent, oak about 16 percent, and ceanothus 12 percent (Table 1).

On the two San Joaquin plots the vegetation consisted of one-year-old brush sprouts and seedlings (Figure 2). Interior liveoak *(Quercus wislizenii)*, flannel bush *(Fremontia californica)*, western mountain-mahogany *(Cercocarpus betuloides)*, and redberry were the principal sprouting species on the areas. Seedlings of wedgeleaf ceanothus, yerba santa *(Eriodictyon californicum)*, and chaparral whitethorn *(Ceanothus leucodermis)* were numerous but did not contribute a large proportion of

Table 1. Ground cover and percentage species composition obtained by charting, line intercepts, and line points on an area 100 by 100 feet located at the Hopland Field Station.

	Ground cover			Botanical composition		
Method	Charting	Intercept	Point	Charting	Intercept	Point
Number of plots	100	20	20	100	20	20
Total sample	10,000	2,000	2,000	10,000	2,000	2,000
Unit	Sq. Ft.	Feet	Number	Percent	Percent	Percent
Adenostoma fasciculatum	3,640.20	713.87	706	71.27	70.48	69.35
Quercus durata	821.76	168.07	172	16.09	16.59	16.90
Ceanothus cuneatus	624.38	128.91	137	12.23	12.73	13.45
Rhamnus crocea	16.44	2.12	3	0.32	0.20	0.30
Ceanothus integerrimus	3.24	0	0	0.06	0	0
Arctostaphylos glandulosa	1.68	0	0	0.03	0	0
Total	5,107.70	1,012.97	1,018	100	100	100

the ground cover. These plots will be referred to as the liveoak plots. Plant size ranged from seedlings about 1 inch in diameter and 3-4 inches in height to clumps of interior liveoak sprouts 4 feet in height and 15 feet in diameter. Although the area had heavy use by deer and cattle, plant boundaries were usually very irregular due to the presence of long leaders on many of the young sprouts. Intermingling of the canopies caused the sum of the cover by species to exceed the total ground cover.

On one plot, ground cover was 24 percent and on the other 18 percent. In the first plot interior liveoak occupied 17 percent of the area, yerba santa seedlings 3 percent, wedgeleaf ceanothus seedlings 1 percent, and mountain-mahogany almost 2 percent. The remainder of the ground cover was contributed by ten species each with less than ½-percent cover (Table 2). On the second plot interior liveoak and flannel bush each occupied 7 percent. Twelve other species made up the remaining ground cover.

Line Transect, Line-point, and Charting Compared for the Chamise Plots

The results from measuring the vegetation by charting, line transects, and line point procedures in the chamise plot are shown in Table 3. There was very little difference in the means obtained by the different methods. All were within the confidence interval calculated at the 5 percent level for any one of the methods. It would seem that these different methods yielded means that were well within the limits required by most objectives in vegetational sampling. The comparison of the means gives little basis for choosing one of the methods as superior to the others. This same conclusion was reached in the comparison of the intercept and line point data from the liveoak plots.

The variance or standard deviation of sampling units was generally much less in both the line transect and the line point methods than with the charting method. The charted plots were more variable than the others. The standard error of the mean in each case was somewhat less conclusive in favor of any of the methods and further indicates that all methods gave accurate estimates of the population mean with the size of sample employed. The coefficient of variation, ratio of standard deviation to the mean, was about the same for the transect methods and both of these were less than for charting. The calculation of the number of plots required to sample within 10 percent of the population mean 95 percent of the time varied greatly. For the total cover the number was 43 for 100 square-foot plots, and 9 or 10 for 100-foot transects. The same relationships exist for the individual species even though the number of plots required to sample them adequately was much greater than for the total cover.

Variation analysis and sample size calculations to obtain means within certain specified limits indicate that both transect methods were superior to charting. Undoubtedly the reason is that the 100-foot lines cross local variations in cover which result in less difference between lines than was the case with plots 10-feet square. The principle of long narrow plots being better than square plots has been well established and is further strengthened by these results.

Paired Transects from the Field and Chart

For the line intercepts and the line points on the chamise plot, one set of data was taken in the field and another comparable set was obtained by sampling from the map of the study area. These two sets were taken in the same location and, therefore, were considered as paired observation and analyzed on a basis of mean differences.

In all cases but one, sampling from the map gave larger numbers for intercepts and points than sampling in the field. The differences were significant at the 99 percent level for the total cover by both intercepts and points and for chamise with the point method (Table 4).

These data are interpreted to indicate that charting of canopy areas gave somewhat higher cov-

Table 2. Ground cover and percentage species composition obtained by line intercept and line points on two areas 100 by 100 feet located on the San Joaquin winter deer range.

	Ground cover in percent				Botanical composition in percent			
	Plot 1		Plot 2		Plot 1		Plot 2	
	Intercept	Line Point	Intercept	Line Point	Intercept	Line Point	Intercept	Line Point
Quercus wislizenii	17.14	17.17	7.27	7.35	68.95	69.32	38.53	39.07
Fremontia californica	0.14	0.10	7.08	7.20	0.56	0.41	37.52	38.28
Eriodictyon californicum	3.07	2.82	0.07	0.01	12.35	11.39	0.37	0.05
Ceanothus cuneatus	1.16	1.40	0.88	0.87	4.67	5.65	4.66	4.63
Ceanothus leucodermis	0.11	0.10	0.38	0.40	0.44	0.41	2.01	2.13
Cercocarpus betuloides	1.54	1.40	0.26	0.22	6.20	5.65	1.38	1.17
Rhamnus crocea	0.39	0.32	1.33	1.30	1.57	1.29	7.05	6.91
Quercus douglasii	0	0	0.76	0.72	0	0	4.03	3.83
Quercus kelloggii	0.45	0.45	0.48	0.42	1.81	1.82	2.54	2.23
Prunus subcordata	0.48	0.55	0.01	0	1.93	2.22	0.05	0
Lonicera interrupta	0.11	0.12	0.12	0.12	0.44	0.48	0.64	0.64
Rhus diversiloba	0	0	0.16	0.20	0	0	0.85	1.06
Ceanothus leucodermis-sprouts	0.10	0.12	0	0	0.40	0.48	0	0
Rhamnus californica	0.11	0.12	0	0	0.44	0.48	0	0
Sambucus coerulea	0.03	0.05	0.04	0	0.12	0.20	0.21	0
Arctostaphylos mariposa	0.03	0.05	0.03	0	0.12	0.20	0	0
Total	24.12[1]	24.20	17.89	17.87	100	100	100	100

[1] This is amount of ground covered by plant canopies and does not equal sum of the cover by species due to intermingling of plant canopies.

erage than actually occurred on the ground. The small t values for oak indicate that it was mapped very accurately. This could be expected because the canopy boundaries were clear-cut and the foliage of broad leaves was closely packed on short branches without interspaces. On the other hand chamise had irregular and indefinite canopy boundaries. Long branches protruding around the edges of each plant incompletely covered the ground so the investigator had to average the irregularities to 100 percent density by ocular means. This evidently resulted in chamise being mapped as an area slightly larger than it actually was. Ceanothus was intermediate between the oak and chamise in these characteristics. Undoubtedly, charting of shrubs is more accurate with some species than with others.

Further Comparisons of Line Intercepts and Line Points

In the sampling of brush, as well as with other vegetational types, decisions must be made on size, number, and location of samples. These items were studied with data from the liveoak plots. The analysis followed a procedure whereby the data for ground cover were accumulated in several different ways. As every successive increment was added the new sum was divided by the new sample size to give a series of means. The types of accumulation were: (1) forty 100-foot lines in the order in which they occurred in the field, (2) forty 100-foot lines in a random arrangement, (3) 800 5-foot segment of lines in a random arrangement, and (4) 4,000 single line points in a random arrangement. The first three of these types of accumulations were done for both intercepts and points. The cover for each species and the total cover was accumulated separately for the two liveoak plots.

An example of the accumulation process is as follows: 242 hits were recorded for the first 1,000 randomly arranged points. The next 100 points with 19 additional hits gave 261. The corresponding means for the 1,000-and 1,100-point samples are 24.2 and 23.7 percent cover, respectively. These are two in series of accumulated means.

With the addition of the last group of points or lines, the final accumulated mean was obtained. The final mean for line intercept was used as the true population mean and deviation of each accumulated mean from the population mean was expressed as a percentage of the population mean and used to construct a series of graphs of which Figure 3 is one example.

For the purpose of this discussion a deviation of 5 percent from the final mean is arbitrarily considered to be a satisfactory intensity or level of sampling. This 5 percent level appears on the vertical plane (Figure 3) as a dotted line. Hereafter, the term "5 percent level" refers to

Table 3. Statistical analyses of ground cover obtained by charting, line intercepts, and line points on the chamise plot.

	Total cover			*Adenostoma fasciculatum*		
Number of plots	100	20	20	100	20	20
Size of plot	10 ft. x 10 ft.	100 ft.	100 pts.	10 ft. x 10 ft.	100 ft.	100 pts.
Unit of calculation	Sq. ft.	Feet	Points	Sq. ft.	Feet	Points
Mean ground cover	51.07	50.65	50.90	36.40	35.69	35.30
Standard error	1.707	1.768	1.720	1.732	1.473	1.565
Coefficient of variation[1]	33.43	15.61	15.12	47.53	18.48	19.83
Confidence interval[2]	±3.35	±3.47	±3.37	±3.39	±2.89	±3.07
Calculated n[3]	43	10	9	87	14	16
	Quercus durata			*Ceanothus cuneatus*		
Mean ground cover	8.22	8.40	8.60	6.24	6.45	6.85
Standard error	1.248	1.288	1.183	0.843	1.253	1.425
Coefficient of variation[1]	151.83	68.57	61.64	135.01	86.79	93.02
Confidence interval[2]	±2.45	±2.52	±2.32	±1.65	±2.46	±2.79
Calculated n[3]	885	181	146	702	290	333

[1] Coefficient of variation equals the standard deviation divided by the mean, expressed in percent.

[2] Confidence intervals equals $\pm t_{.05}$ for infinite degrees of freedom multiplied by the standard error.

[3] Calculated sample size equals $\frac{t^2 C^2}{P^2}$, where t is at 0.05, C is the coefficient of variation, and P is 10 percent of the mean.

this deviation and does not denote probability of error in the statistical sense.

With all of the species together and with single species having ground cover greater than 3 percent, the deviation of the accumulated means from the real mean showed very small differences between line intercepts and line points. This is illustrated for total vegetation at a cover of 24 percent (Figure 3), and was true for several species on both plots. The parallel nature of the paired lines for points and intercepts suggests that the two procedures give similar results at various sample sizes.

With species having densities of 3 percent or less the divergence of accumulated means between line intercept and line points for most of the sample sizes was large. This is illustrated for wedgeleaf ceanothus seedlings at a ground cover of 1 percent (Figure 4) and was found with the other species of low cover. With these species there is little assurance that either points or intercepts give an adequate sample. However, the line intercepts exhibited less fluctuation and this method is probably the best for sampling the species with low cover.

Comparative results of the random and systematic methods of sampling is shown by the size of sample required by each method to bring the deviation of the accumulated means within the 5 percent level (Figures 3 & 4 and Table 5). When the data for total vegetation were randomized, the sample size necessary to reach the 5 percent level was usually smaller than with non-random accumulations. The longer the line or the larger the sample size the more total feet of line is needed for an adequate sample. The 5-foot line segments were the least variable in sample size between species of different ground covers.

In general, the data show that for species with intermediate and higher ground covers, line points will give means little different from line intercept at a reasonable sample size. With species of low cover, the percentage variation between the points and intercepts is high and samples must be large and would seldom be practical. Although there were inconsistencies, the trend was for the sample size necessary to reach the 5 percent level to decrease with randomization of successively smaller sampling units.

In sampling, the practical aspects as well as accuracy and precision must be considered. Randomization of samples can be accomplished by the use of coordinate lines but this would involve a great deal of work. It is difficult to move about in many brush fields.

Systematic sampling can be with lines several hundred feet in length. With this type of sampling the number of lines required to sample within the desired level of precision would be larger than with any of the random methods. However, the ease

Table 4. Mean difference analysis for paired transects sampled in the field and from the map of ground cover for the chamise plot.

	Line points				Line intercepts			
	Afa[1]	Ccu	Qdu	Total	Afa	Ccu	Qdu	Total
Mean difference	2.55	0.50	0.05	3.2	1.57	0.70	0.08	2.40
Greatest	Map	Map	Map	Map	Map	Map	Field	Map
Standard error	0.844	0.471	0.576	0.882	0.852	0.388	0.458	0.742
$t_{.01}$	3.02**	1.061	0.087	3.628**	1.84	1.80	0.175	3.24**
Confidence interval	±1.76			±1.84				±1.55

[1] The species are *Adenostoma fasciculatum, Ceanothus cuneatus,* and *Quercus durata.*

**Significant difference at the 0.01 level.

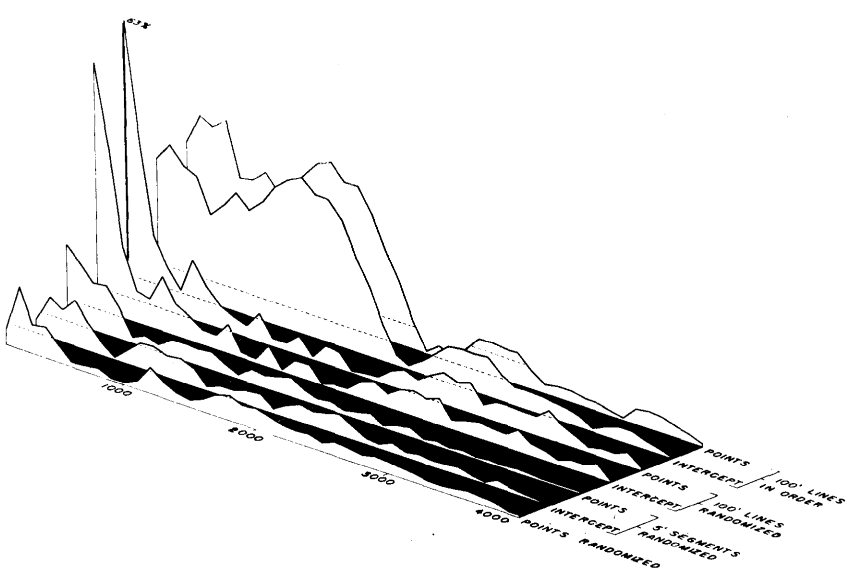

FIGURE 3. Percentage deviation of accumulated means from the population mean for total vegetation on the liveoak plot with a density of 24 percent. Dotted lines on vertical planes show the 5 percent level of deviation. White lines across the base plane indicate sample sizes in feet or the equivalent number of points. See text for explanation of calculations.

of establishing and sampling such lines make them the more practical.

Field and Office Time Required by Transects

The time required to read each line of intercepts and points in the field and the initial summarization of each in the office was recorded for the chamise plot. For both field recording and initial summarization combined, the line point method took about one-third as much time as the line intercept (Table 6). Even though it was not recorded the time required to chart a 100-square-foot plot was more than for a 100-foot line of intercepts.

The point method had a great advantage over the other methods in office time. To tally the points required only a count, while the charting method necessitated measurements of areas with a planimeter, and the intercepts required summation. The calculations were also much easier with the point method because whole numbers with two significant digits constituted the data, while with the other methods mixed numbers were used. The smaller numbers lend themselves to fewer errors in calculations than the larger numbers.

The time required to take a line of intercepts and of points at two brush densities in the liveoak area was determined by two operators. Each required over twice as much time to measure the intercepts as the line points. When 5 minutes for line establishment was added to the reading time, the ratio of time was 1.6 to 1.8 in favor of the points (Table 7). Density of the second line was 3 times that of the first, which resulted in a time increase for both methods by 20 to 50 percent.

When IBM cards are used to record the data, the fewer number of digits necessary for line points necessitates fewer columns for a given unit of line and more information may be punched on each card. With fewer cards less time and expense are involved in punching, sorting and any other machine processing necessary.

The total time required in the field and office was closely related to the number of plants in one case and the size of plants in another. On the chamise plots the correlation coefficient between numbers and time was 0.7878 for points and 0.6453 for intercepts. These were both significant at the 99 percent level. Larger sprouts rather than more plants resulted in more time per transect in the liveoak plots.

Even though analysis of the

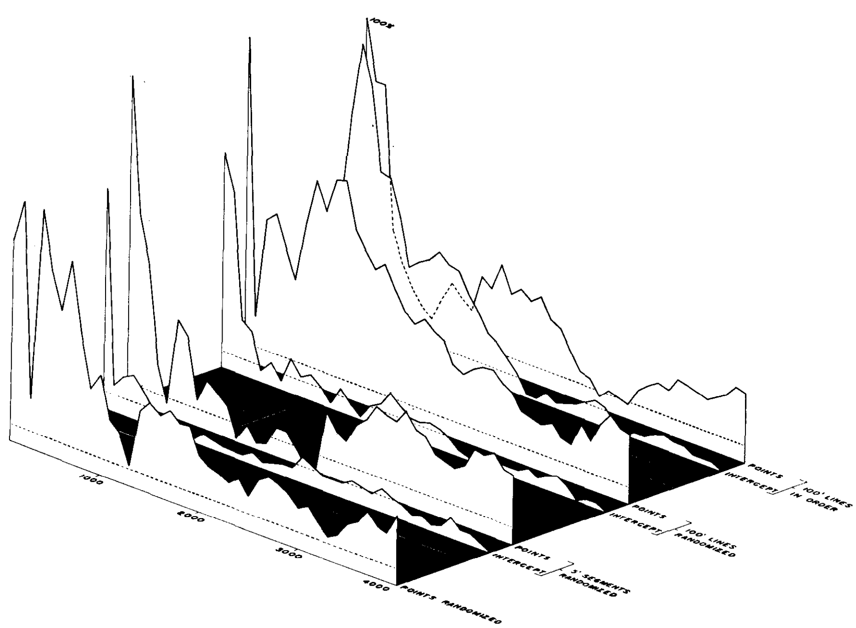

FIGURE 4. Percentage deviation of accumulated means for wedgeleaf ceanothus seedlings at a ground cover of 1 percent. See Figure 3 and text for complete explanation.

Table 5. Number of feet in a sample required to bring the deviation of accumulated means within the 5 percent level for 4 sampling methods.

	Line points randomized	5-foot line segments randomized	100-foot lines randomized	100-foot lines in order
Total vegetation, ground cover-24.12 Percent	400	600	900	2,000
Total vegetation, ground cover-17.89 Percent	1,000	600 (700)[1]	1,200	2,000
Interior liveoak, ground cover-17.14 Percent	400	600	900	1,900
Interior liveoak, ground cover-7.08 Percent	2,600	600	1,300	1,900

[1]700 feet were required for line points. All other sample sizes were the same for points and intercepts.

variation and of differences between sample means and population means did not indicate one of the transect methods to be superior, except at plant densities below 3 percent, an analysis of the time required in sampling marked the line point method as the one to use. If the same amount of time were put into both methods, the investigator would have a larger sample with the line point technique and consequently a better estimate of the population.

Sample Size with Species of Different Cover and Distribution

In this as in most studies of vegetation, data were collected on several species. These species varied widely in foliage cover. Generally, the lower the cover, the greater the ratio of standard deviation to the mean and the larger the sample required (Tables 3 and 5).

An assumption of normality in the population being sampled is usually made although normality may or may not exist. This is illustrated by an analysis of frequency distribution of crown cover by five percent classes in the chamise plot (Figure 5). The bar graphs show the actual frequencies for total cover and chamise and the calculated normal curves for a population with the same mean, standard deviation, and number of items. For total cover the actual population differs from the normal by a Chi square of 12.544 for 9 degrees of freedom. The probability is between 80 and 90 percent that the population is normal. The distribution of density classes of chamise also follows the normal but is a little more divergent than that of the total of all species. However, the probability is still between 80 to 90 percent that the population is normal. Both curves are slightly skewed toward the higher density classes and slightly flattened.

For oak and ceanothus the distributional curves of ground cover take an entirely different shape. With both, a large number of plots had no plants and with increasing cover there were fewer plots. These distributions seem to fit paraboloid curves best.

Frequency of crown cover by 5 percent classes was determined for the liveoak plots. The distributions obtained were similar to

Table 6. Average time in minutes to record each transect in the field and to summarize field sheets for the chamise plot

	Line points	Line intercepts
Field time	7.81	16.18
Summary time	0.75	10.46
Total	8.56	26.64

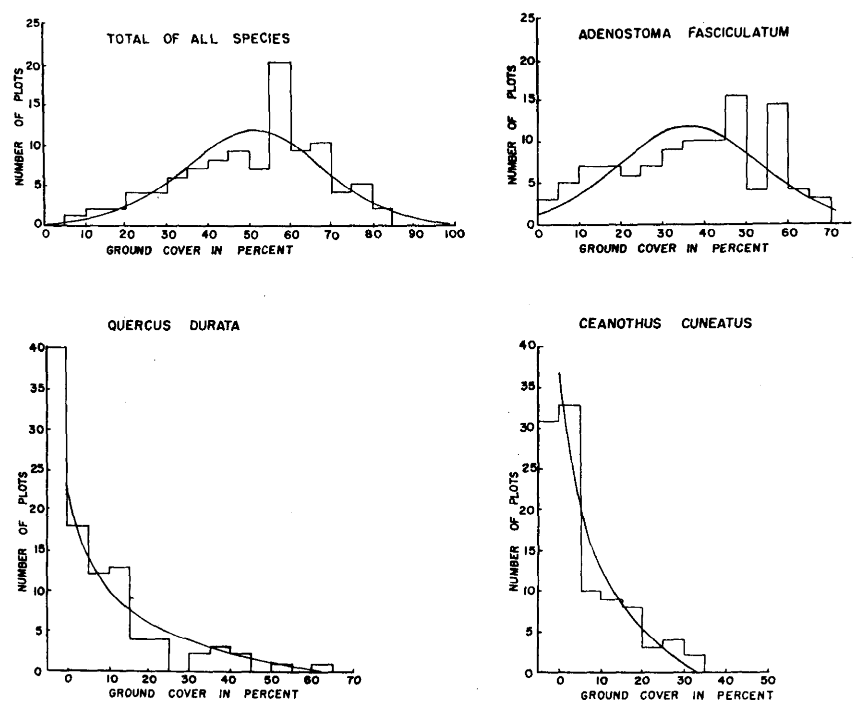

FIGURE 5. Frequency distribution of 100 plots according to 5 percent cover classes of the major brush plants on the chamise plot. The curves were calculated with the same mean, standard deviation, and number of items as the data in the bar graph.

Table 7. Time in minutes to establish and record two transects by two men in the area of the liveoak plots.

	Percent density	Operator 1			Operator 2		
		Intercepts	Points	Ratio	Intercepts	Points	Ratio
Line 1	18.37	18:06	11:30	1.6	23:35	13:05	1.8
Line 2	56.37	26:45	14:35	1.8	29:35	16:00	1.8
Ratio	3.1	1.5	1.3		1.3	1.2	

those of the low-density species in the chamise plot. None approached a normal distribution.

Frequency distributions are greatly influenced by the size of field plots and by the class intervals into which the plots are grouped. These data are shown to indicate only that each species exhibits a separate type of distribution. Thus, each species constitutes a distinct population and combinations of species make still additional populations.

In this study of cover by several species and three totals, all but one species and one total exhibited extreme positive skewness in distribution. However, the seriousness of non-normality is not great because sample means from such populations are normally distributed about the population mean provided the number of items in the sample is large (Feller, 1950; and Madow, 1948). The nearly normal distribution of 200 sample means of 20 random line points from the total cover of one liveoak plot illustrates this principle (Figure 6).

The use of normal procedures with skewed data may lead to misinterpretation. Generally, wrong inferences about the population mean will be concentrated on one side of the confidence belt. With great positive skewness, a large proportion of the wrong statements will be above the upper confidence limit. Another effect of non-normality is to produce high variability in the variance from one sample to another.

A sample which is based on the total cover, and is adequate or within the limits set by the investigator as satisfactory, may not sample any of the individual species adequately. On the other hand, the number of plots needed to sample the species of lesser importance may be so great that the sampling is beyond the facilities of the investigation. The investigator must be aware of these difficulties in order to make an intelligent decision as to sample size and to draw only those conclusions warranted by the data. Few guide lines or rules of thumb can be established except through preliminary sampling of the population being studied.

Ordinarily an estimate of sample size should be made for each item in the investigation. If the indicated n's are close together, the investigator is fortunate and can proceed. If the n's are somewhat divergent, he has several choices of sample size. He may regard those items which are most important to him and disregard the others completely. Or, he may choose a size that will over-sample some species in order to get precise information on others. He also has available a choice of different sampling procedures for the different components of the vegetation. He may relax his standards of precision or choose different ones for the different species.

The choice of these alternatives is one to be made by the investigator and is based on the objectives of his study and on the funds and time that he has available. Cochran (1953) has given some guide lines that are helpful. A simple random sample with low sampling ratio is indicated when the species has a widespread and even distribution. As the frequency of occurrence decreases, the sampling ratio must be increased by an increase in either or both the number and size of plots. Stratified sampling is indicated for species which are absent from some areas and abundant in others. This may be accomplished with the addition of supplementary sampling to a general random sample. There are many other ways to stratify. When a species is concentrated in a small part of the study area, a simple random sample of the whole area is totally inadequate. Sampling should then be geared specifically to the distribution of the species.

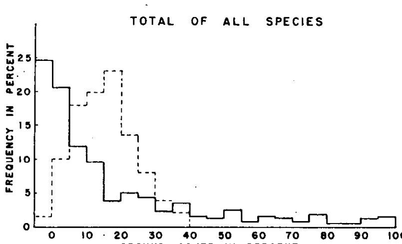

FIGURE 6. Solid line is the frequency distribution of 400 plots according to 5-percent-ground-cover classes of the entire brush cover on one of the liveoak plots. Dashed line is the frequency distribution of 200 sample means of 20 random points taken from the same population.

Summary

The foliage cover of mixed shrubs on an area 100 feet on a side was completely mapped and sampled by the line intercept and line points.

The means and confidence intervals obtained by the three methods indicated that all three will give reliable estimates of the population mean. Both the transect methods yielded less variable data and will sample adequately with fewer plots and less effort than the charting procedure. The transect procedures gave approximately equal results with the same total length of line for species with ground

cover over 3 percent. However, the line point method took less time and is, therefore, recommended as the best of the three methods to sample areas of shrubs for percentage species composition on a basis of ground cover.

Paired transects in the field and on the chart suggested that charting was more accurate for oak than for chamise. This is explained on the basis that canopy boundaries were much more definite for oak than for chamise. It also suggests that charted quadrats in the types of brush sampled gave slightly higher cover than the transects.

Distribution of 5-percent-ground-cover classes with plots 10 x 10 feet by charting approximated a normal curve for total cover and chamise on one plot. The distribution of oak and ceanothus on the chamise plot and all species in the liveoak plots as determined by intercepts were non-normal by being greatly skewed toward the low density classes. The influence of non-normality on sampling and the reliability of inferences drawn from such samples is discussed.

Species with ground cover of less than 3 percent require extremely large samples. The line intercept method sampled these species better than the line point method.

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