Frequency Sampling of Blue Grama Range[1]

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Highlight

A quadrat 2 inches square satisfactorily sampled frequency distribution of blue grama but a complementary quadrat 16 inches square was needed to sample associated species. A tallying technique was developed using beads and plastic tubes.

The frequencies that species are found present in quadrats of appropriate sizes represent an abstraction or blend of density (number of plants per unit area) and dispersion characteristics. Since these characteristics of perennial vegetation are relatively stable seasonally but variable with sites and grazing treatments, frequency-sampling should be useful for the classification of sites and responses to grazing (Hanson, 1934). If so, advantages of simplicity, objectivity, and speed should be gained with the substitution of frequency techniques for commonly used cover and basal area techniques.

This paper gives the results of studies undertaken to determine procedures for frequency sampling of blue grama range. The development of frequency-sampling techniques required the selection of appropriate quadrat sizes, the determination of efficient allocations of sampling units, the estimation of a satisfactory sample size, and the instrumentation of data recording. Frequency (p) is defined as p = m/n where m is the number of quadrats containing a given species and n is the total number of quadrats observed. We express frequencies in percentage.

Materials and Methods

Theoretical considerations involved in determining appropriate quadrat sizes (Curtis and McIntosh, 1950) and efficient allocations of sampling units (Cochran, 1953) for frequency sampling were reviewed in a recent

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paper (Hyder, et al. 1963). An appropriate quadrat size is defined as one that allows a frequency of 63 to 86 percent for a "most frequent" species. Thus, trial-and-error sampling was undertaken with quadrat sizes of 4^2, 3^2, and 2^2 inches (4 by 4, etc.) to find one that sampled blue grama *(Bouteloua gracilis)* in this frequency range. A primary objective in frequency sampling is to obtain mean frequencies larger than 5 percent but smaller than 95 percent for all species of interest because low and high mean frequencies can result from badly skewed distributions. Since a quadrat small enough to sample blue grama at a desired frequency was effective for only 4 other species, two quadrat sizes were needed to sample this vegetation. The small one was determined by trial and error and a large complementary one by theoretical relations between areas and frequencies.

Complementary quadrat sizes were used separately in sampling to determine efficient allocations of sampling units. A macroplot 200 feet square was sampled three times with each quadrat size. Each sample included 600 quadrats allocated 25, 50, or 100 per transect and requiring 24, 12, or 6 transects per sample, respectively. The transects were perpendicular to a base line and located at restricted random distances along it, half the transects being restricted to the first 100 feet and half to the second 100 feet. Quadrats were located systematically along the transects with 8-foot intervals among 25 quadrats, 4-foot intervals among 50, and 2-foot intervals among 100.

Efficiency is determined by both cost and variance considerations. We measured the time required to establish 24 transects and prepare 24 data sheets independent of sampling times, and the times required to place and read quadrats allocated 25, 50, and 100 per transect independent of transect establishment. The times required were expressed in minutes as transect/quadrat ratios representing cost components c_t/c_q. These ratios enter the calculation of an optimum number of quadrats per transect (k_{opt}). Variance components for quadrats (s_q^2) and transects (s_t^2) were computed for each of the 6 frequency samples by the equations

$$s_q^2 = k(\Sigma pq)/n(k-1) \quad (1)$$

$$s_t^2 = \frac{\Sigma p^2 - (\Sigma p)^2/n}{n-1} - \frac{s_q^2}{k} \quad (2)$$

where k is the number of quadrats per transect, n is the number of transects in the sample, p is the frequency percentage that a given species is present on any transect, and q is 100-p (Cochran, 1953). The variance components were entered with cost components into the calculations of

$$k_{opt} = \sqrt{s_q^2\, c_t / s_t^2\, c_q} \quad (3)$$

Having determined appropriate quadrat sizes and optimum numbers of quadrats per transect, we estimated the number of transects (N) needed at appropriate levels of precision by the equation

$$N = 4nV_p/(\text{e.c.i.})^2 \quad (4)$$

where n is the number of transects already sampled, V_p is the variance of the mean frequency percentage of a given species, and e.c.i. is an expected-confidence-half interval (Snedecor, 1956, p. 501). Since variances are correlated with frequency percentages, a complete set of expected-confidence-half intervals were computed from

$$\text{e.c.i.} = \pm\, 2\sqrt{pq/n\text{-}1} \quad (5)$$

where p is the frequency percentage, q is its complement (100-p), and n is the total number of quadrats (Snedecor, 1956, p. 502). This calculation determines for each frequency percentage an average confidence-half interval that can be used in equation 4 even though confidence limits for binomial distributions are non-symmetrical (Snedecor, 1956, p. 4).

Frequency percentages were derived for all species encountered. To be present in a given quadrat, the center of an individual plant or half its area must be inside the quadrat frame. Our ground rules defined single stems or tillers viewed at ground level as individuals of all grasses, forbs, and shrubs. A lobe was described as an individual of cactus *(Opuntia polyacantha)*. We would have preferred a clump as an individual grass, but clumps usually are indistinct on this range. The ground rules for grasses and cactus obviously invoke a localized contagiousness in the dispersion of units identified as individuals. The species sampled at frequencies >5 percent but <95 percent are treated statistically.

Forty-eight 100 by 75-foot macroplots, located on a "sandy plains" range site grazed heavily since 1939, were sampled in 1963 and summarized to estimate the number of macroplots needed per site assuming the same precision as obtained per macroplot.

Results

Appropriate Quadrat Sizes.—A 2^2-inch quadrat included blue grama in 70 percent of all placements, but frequencies with 4^2 and 3^2-inch quadrats exceeded 86 percent. From equation 7, it is estimated that a 1.8^2-inch quadrat would sample blue grama at 63 percent and that a 2.6^2-inch quadrat would sample it at 86 percent. Smaller and larger quadrats would be less appropriate. Frequencies were above 5 percent for only five species with the 2^2-inch quadrat (Table 1), and a complementary large quadrat size was needed.

To compute the theoretical maximum allowable difference in areas of a complementary pair of quadrat sizes, we assume that a frequency of 5 percent in a small quadrat is marginal and that such a species should be sampled at 95 percent, the upper marginal limit, with a larger quadrat. If the individuals of a species are dispersed randomly, the density (number) per quadrat (d) is given by

$$d = -\log_e (1\text{-}p/100) \quad (6)$$

Table 1. Frequency percentages of the eight most common species using quadrats of appropriate sizes.

Species	Frequencies using quadrats measuring	
	2^2 in.	16^2 in.
	- (Percent) -	
Bouteloua gracilis (H.B.K.) Lag.	70	100
Buchloe dactyloides (Nutt.)Engelm	25	61
Festuca octoflora Walt.	16	52
Carex heliophila Mack.	14	57
Opuntia polyacantha Haw.	8	53
Sphaeralcea coccinea (Pursh) Rydb.	1	20
Plantago purshii Roem. & Schult.	1	18
Leucocrinum montanum Nutt.	<1	6

in which p is the frequency percentage (Curtis and McIntosh, 1950). Letting $p_1 = 5$ percent, then $d = -\log_e (.95) = .05$ per small quadrat of area a_1. Subsequently, we calculate the area (a_2) of a large quadrat giving $p_2 = 95$ percent by the equation

$$a_2 = \frac{[(\log_{10} q_1 - \log_{10} q_2) + .4343\ D\ a_1]}{.4343\ D\ a_1} \quad (7)$$

in which $q_1 = 100 - p_1 = 95$, $q_2 = 100 - p_2 = 5$, and $D = d = .05$ if $a_1 = 1$ (Hyder, et al., 1963).

Thus, $a_2 = [(\log\ 95 - \log\ 5) + (.4343)\ (.05)\ (1)]\ /\ (.4343)\ (.05)\ (1) = 60$; meaning that the area of a large quadrat can be as much as 60 times larger than that of a small quadrat. If a small quadrat samples a randomly dispersed species at a frequency of 5 percent, a larger quadrat with 60 times the area of the small one should sample that same species at a frequency of 95 percent.

To compute the lower limit in the size of a complementary large quadrat, we assume that a species sampled at 10 percent with a small quadrat should be sampled at 90 percent with the large one. Thus, the large quadrat would be at least 22 times the area of the small one. These limits in complementary quadrat sizes are plotted in Figure 1. Quadrat sizes of 2^2 and 16^2 inches were selected for detailed sampling to determine optimum allocations.

Optimum Number of Quadrats per Transect.—The establishment of 24 transects and preparation of 24 data sheets required 59 minutes — 2.46 minutes per transect exclusive of sampling time. Sampling time per quadrat decreased with an increase in the number of quadrats per transect, and was greater with the large quadrat than with the small one. Transect/ quadrat cost ratios computed from sampling times (Table 2) indicate greater efficiency when the number of quadrats are increased relative to the number of transects.

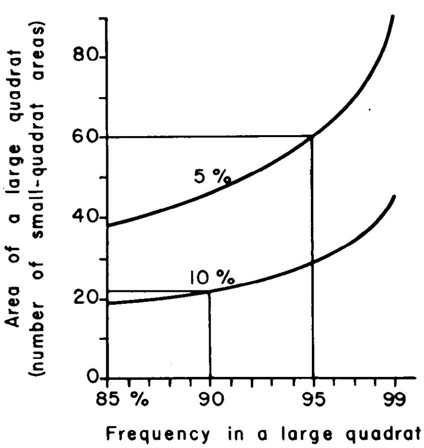

FIGURE 1. The area of a large quadrat needed to sample a species at a frequency > 85 percent when its frequency is 5 or 10 percent in a small quadrat.

Table 2. Transect/quadrat cost ratios (c_t/c_q), quadrat/transect variance ratios (s_q^2/s_t^2), and optimum numbers of quadrats per transect (k_{opt}) as calculated from 6 independent frequency samples.

Sample description			Sample results[1]		
Quadrat size	No. of quadrats per transect (k)	No. of transects per sample (n)	c_t/c_q	s_q^2/s_t^2	k_{opt}
2^2 inches	25	24	18/1	18/1	18
2^2 inches	50	12	24/1	16/1	20
2^2 inches	100	6	24/1	41/1	31
16^2 inches	25	24	6/1	14/1	9
16^2 inches	50	12	9/1	8/1	8
16^2 inches	100	6	11/1	6/1	8

[1] Variance components s_q^2 and s_t^2 were averaged among species and expressed in ratio form.

Variance components were computed for individual species in each sample. In general, variances decreased with more quadrats per transect and were larger for the 16 by 16-inch quadrat than for the 2 by 2-inch one. Quadrat/transect variance ratios averaged among species varied from 41/1 to 6/1 (Table 2), and enter equation 3 for the calculation of k_{opt}.

The optimum number of quadrats per transect (k_{opt}) was calculated from cost and variance ratios in each of the 6 samples. Average results were 23 quadrats per transect with the 2 by 2-inch quadrat and 8 with the 16 by 16-inch one (Table 2). The range in k_{opt} is wider with the small quadrat than with the large one.

Number of Transects per Sample.—Expected-confidence-half intervals were computed by equation 5 (Hyder, et al., 1963). In these computations, n-1 was given a value of 100 so that the half interval would be 10 percent at a frequency of 50 percent. Smaller or larger half intervals can be computed where more or less sampling precision is needed. The expected-confidence-half intervals enter equation 4 for estimating the number of transects needed in a sample. Sample sizes were estimated from variances with each quadrat size when 25 quadrats were observed in each of 24 transects. Sample sizes estimated in this way vary greatly among species, but average 8 transects (200 quadrats) with the small quadrat and 9 transects (225 quadrats) with the large one (Table 3).

Data Recording.—Since frequency sampling accumulates data rapidly, an instrumentation technique can improve accuracy and speed. A line-connected dot system of 4 dots and 6 lines was used to record species presences as called. But field errors and office tabulation requirements indicated a need for an improved technique. Since we need to determine the frequencies of as many as 80 species in a series of samples, commercial tally registers were unsatisfactory. The recording technique developed involves dropping 9 mm. plastic beads into 10 mm. i.d. clear plastic tubes supported in a wooden frame (Figure 2). The tubes are mounted in 10 units of 10 tubes each and prelabeled so far as possible with 4-letter species symbols in alphabetical order. An observer calls out the species present and a re-

Table 3. Number of transects needed per sample when 25 quadrats are taken per transect.

Species	Number of transects needed with quadrat sizes of 2^2 in.	16^2 in.
Bouteloua gracilis	5	
Buchloe dactyloides	15	20
Festuca octoflora	14	19
Opuntia polyacantha	4	3
Carex heliophila	3	9
Sphaeralcea coccinea		4
Plantago purshii		6
Leucocrinum montanum		5
Average	8	9

FIGURE 2. A recorder drops beads into labeled plastic tubes as an observer calls out the species present in quadrats.

corder drops beads into corresponding tubes. At the end of each transect, the bead tallies are expressed in percent and recorded directly on printed record sheets that include columns for sample means and variances.

Number of Macroplots per Site.— The 48 macroplots located on the "sandy plains" range site were sampled with nested 2^2 and 16^2-inch quadrats allocated 25 per transect with 10 transects per macroplot. Frequencies were recorded for each quadrat size. Ten species were recorded at frequencies of 5 to 95 percent (Table 4). The number of macroplots needed for each of these species was estimated by equation 4. These estimates varied from 2 to 19 with a mean of 12.

Discussion

A pair of complementary quadrat sizes were selected for frequency sampling of blue grama range because one small enough to sample blue grama at a frequency between 63 and 86 percent was suitable for only 4 other species. The small quadrat is 2^2 inches and the large one 16^2 inches. The area of the large quadrat is near the theoretical limit of 60 times the area of the small quadrat.

The optimum number of quadrats per transect was 23 with the small quadrat and 8 with the large one. However, sampling with a pair of quadrats would be more convenient if these were nested for simultaneous viewing, and furthermore, if the number of quadrats per transect allowed easy mental transformation to frequency percentages. Twenty or 25 quadrats per transect would be convenient and reasonably efficient for each quadrat size.

Ten transects (250 quadrats) per macroplot will sample most species within the limits of the expected-confidence-half intervals used. A sample size of 250 quadrats is less than half as large as those taken for the development of frequency sampling techniques. We used a macroplot 200 by 200 feet in size when sampling for efficient allocations, but reduced this to 100 by 75 feet when sampling for site description.

An average of 12 macroplots were needed in sampling the "sandy plains" range site with site precision equal to macroplot precision. This indicates considerably more variation for some species on this range site than has been implied in site descriptions. If other sites are equally variable, vegetation descriptions for sites often may be drawn from inadequate samples. On the other hand, trends in species succession can be determined from internal variances from permanent macroplots located on "key areas" and sampled in different years.

Table 4. Mean frequencies and numbers of macroplots needed to sample various species on the "sandy plains" range site.

Species	Mean Frequency[1]	Number of macroplots needed per site
Bouteloua gracilis	82	5
Opuntia polyacantha	43	18
Sphaeralcea coccinea	32	8
Aristida longiseta Steud.	25	11
Sporobolus cryptandrus (Torr.) A. Gray	19	11
Eriogonum effusum Nutt.	19	19
Carex heliophila	16	16
Agropyron smithii Rydb.	6	11
Stipa comata Trin. & Rupr.	6	17
Gaura coccinea Nutt.	5	2

[1] Frequency in 2^2-inch quadrats for *Bouteloua* and in 16^2-inch quadrats for other species.

In the adaptation of these frequency sampling techniques to other sites, one should select an appropriate quadrat size or a pair of complementary quadrat sizes, which may or may not be the same sizes that we selected for blue grama range. Since optimum efficiency in sampling is approached with a rather wide range in the allocation of sub-sampling units, a standard procedure of taking 20 to 25 quadrats (of each size) per transect may be considered convenient and reasonably efficient for all sites. In subsequent application of the techniques we have established sample areas (macroplots) 100 feet long by 75 feet wide and have sampled each with 10 transects of 25 quadrats (2 sizes nested) per transect (a total of 250 quadrats of each size per macroplot). The percentage of quadrats containing each species is recorded for each transect.

Summary

Experiments were conducted to determine appropriate quadrat sizes, efficient allocations of sampling units, satisfactory sample sizes, and data accumulation techniques for frequency sampling of blue grama range. We selected a 200 by 200-foot macroplot on representative range and determined a pair of appropriate quadrat sizes by trial-and-error sampling with several sizes. A small quadrat 2^2 inches was appropriate because it included blue grama, the most frequent species, in about 70 percent of placements. However, this small quadrat sampled only 4 other species at frequencies above 5 percent. Since we want to encounter nearly all species and to sample most of them at frequencies between 5 and 95 percent for statistical considerations, a large quadrat (16^2 inches) was needed to complement the small one. A large complementary quadrat should be about 60 times the area of the small quadrat.

These quadrat sizes were used separately in sampling a macroplot. A total of 600 quadrats allocated 25, 50, or 100 per transect were

observed with each quadrat size making 6 independent samples. Quadrat/transect cost and variance components from these samples entered the calculation of the number of quadrats per transect needed for optimum efficiency. Eighteen to 31 quadrats per transect were most efficient with the small quadrat, and 8 or 9 were most efficient with the large one. When taking 25 quadrats per transect, 9 transects per macroplot gave satisfactory sample precision with each quadrat size. We suggest that 250 quadrats per macroplot allocated 25 per transect are equally convenient and efficient, and that where a complementary pair of quadrats is needed they may be nested for greater sampling convenience.

The percentage of quadrats containing each species is recorded for each transect. A tallying technique developed involves dropping beads into plastic tubes as an observer calls out the species present in quadrats. The tubes are mounted in 10 units of 10 tubes each and prelabeled with 4-letter species symbols in alphabetical order.

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