The determination of an optimum sampling technique for biomass of herbaceous vegetation in a Central Australian woodland

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Abstract

The green standing material, dry standing material and litter in the herbaceous layer of a Central Australian woodland were sampled using sets of nested quadrats of various proportions.

By minimising the product of the time required to obtain the data and the relative variances of the mean weights of material, the optimum size of quadrat necessary for estimating biomass was found to be 1 square metre or less. The optimum shape was 1:16 for litter but there was no preferred shape for green or dry material in this case.

No edge effect was detected.

A method is given for determining the optimum number of quadrats for a known mean, variance and cost.

Introduction

An important requirement of any vegetation study is a suitable sampling technique. Most techniques for estimating biomass have been evolved in temperate climates and they may not be appropriate in arid environments. The distribution of arid zone vegetation can be highly irregular and sparse, so that the size and number of quadrats required for a representative sample may need to be greater than in temperate or tropical climates. In addition, the conventional square quadrat may not be appropriate.

A quadrat of 1 square metre or less is commonly used in temperate climates for sampling herbaceous species e.g. Wiegert and Evans (1964) and for sampling litter e.g. Gosz *et al.* (1973). Bray *et al.* (1959) used larger quadrats for some sampling but the dominant herbaceous species were up to 3 metres high. On the other hand, Pechanec and Stewart (1940) recommended sampling subunits of 50 square feet in sagebrush - grass range in Idaho, and that these units be circular.

A square quadrat has been the most consistently used shape in vegetation studies, while a circular shape is the most efficient for reducing the 'edge effect'. The edge effect is the bias which arises when vegetation is being clipped along the edge of a quadrat and the worker must choose what to include or exclude. The elongate rectangle has been found to be most efficient in incorporating maximum variation within quadrats and ensuring minimum variation between quadrats (Christidis 1931, Jain 1967). The limit to the elongate shape is the increasing error of the edge effect.

The number of quadrats used in sampling has an upper limit set by the time available for the work. Since the variance of the mean is inversely proportional to the number of quadrats required to determine it, the lower limit is set by the amount of error that can be tolerated.

This work is an attempt to optimise the size, shape and number of quadrats necessary for future studies of productivity in Central Australian woodlands. The optimum quadrat size and shape were determined by compromise between the variance of the mean weight of collected material and the cost, measured in terms of time. These calculations were made for three categories of vegetation: green standing material, dry standing material and litter. The optimum number of quadrats could be calculated from the variance of the mean of the best sized and shaped quadrat and the acceptable level of error, which is also limited by time.

The Study Area

In the Central Australian rangelands, a number of different vegetation associations (range eco-units) can be delineated and several of these are important to the pastoral industry. The open woodland eco-unit in which this study is based consists of scattered trees (Atalaya hemiglauca, Acacia aneura, A. kempeana, A. estrophiolata, Hakea suberea), scattered shrubs (Eremophila spp., Cassia spp.) and ground cover of low-growing forbs and grasses, predominantly Aristida contorta and Enneapogon spp., which are a source of forage for cattle. Annual rainfall averages 250 mm. but has been above 500 m. for 1973-1975.

Methods

Field sites were selected subjectively on the basis of species composition typical of open woodland. Sites were not placed close to trees because the area of vegetation subject to their influence was only a small proportion of the whole. Four sites within a radius of 1 km. of a marker post were chosen and four randomly selected replicates of the required material was collected at each site within an area of ¼ hectare, giving a total of sixteen replicates.

At every sampling position, three sets of three nested quadrats were laid out as in Fig. 1 (a), (b), and (c). By addition, the possible number of quadrat sizes was seven in each set, with relative areas as follows:-
1 (0.25 sq.m.),
3 (0.75 sq.m.),
4 (1.00 sq.m.),
12 (3.00 sq.m.),
13 (3.25 sq.m.),
15 (3.75 sq.m.),
16 (4.00 sq.m.)
Sizes 1,3,4,12 and 16 were used (Wiegert 1962). Altogether, sixteen replicates of the three sets of quadrats were made as this number was thought to be more than sufficient for any future work with a limit on time.

Each of the nested quadrats was clipped separately, and the litter was collected separately from each. The material was oven dried at 80°C and, after separation of the clipped samples into green and dry components on the basis of whether they were green coloured or not, the three categories of vegetation (green standing, dry standing and litter) were weighed. The time taken for each part of the operation was recorded.

Results and Discussion

The mean weight and variance per square metre of the mean weight of each category of vegetation for each quadrat size and shape and the mean time taken for processing, or cost, is presented in Table 1.

Wiegert (1962) proposed that "the cost of a single quadrat.....consists of a fixed cost, c_f, which is independent of the size of the quadrat (walking between stations, weighing etc.) plus x times a cost, c_v, which is the time spent clipping and sorting a quadrat of size 1". 'x' is the quadrat size. He estimated the relative cost $C_r = (c_f + xc_v) / (c_f + c_v)$, for the various quadrat sizes and proposed that the optimum quadrat size be chosen by minimising $C_r . V_r$, where V_r is the relative variance of the mean. He apparently did not test for statistically significant differences between the various values of $C_r . V_r$.

In the data reported here, c_f was such a small proportion of the total cost that it was included in a single cost measurement 't' and variance was simply expressed per square metre 'V'. The optimum quadrat size and shape was chosen by minimising t.V. Tests showed correlation of t and V at the 0.1 level of probability in only three out of twenty-seven sets of comparisons. This was taken to be an ade-

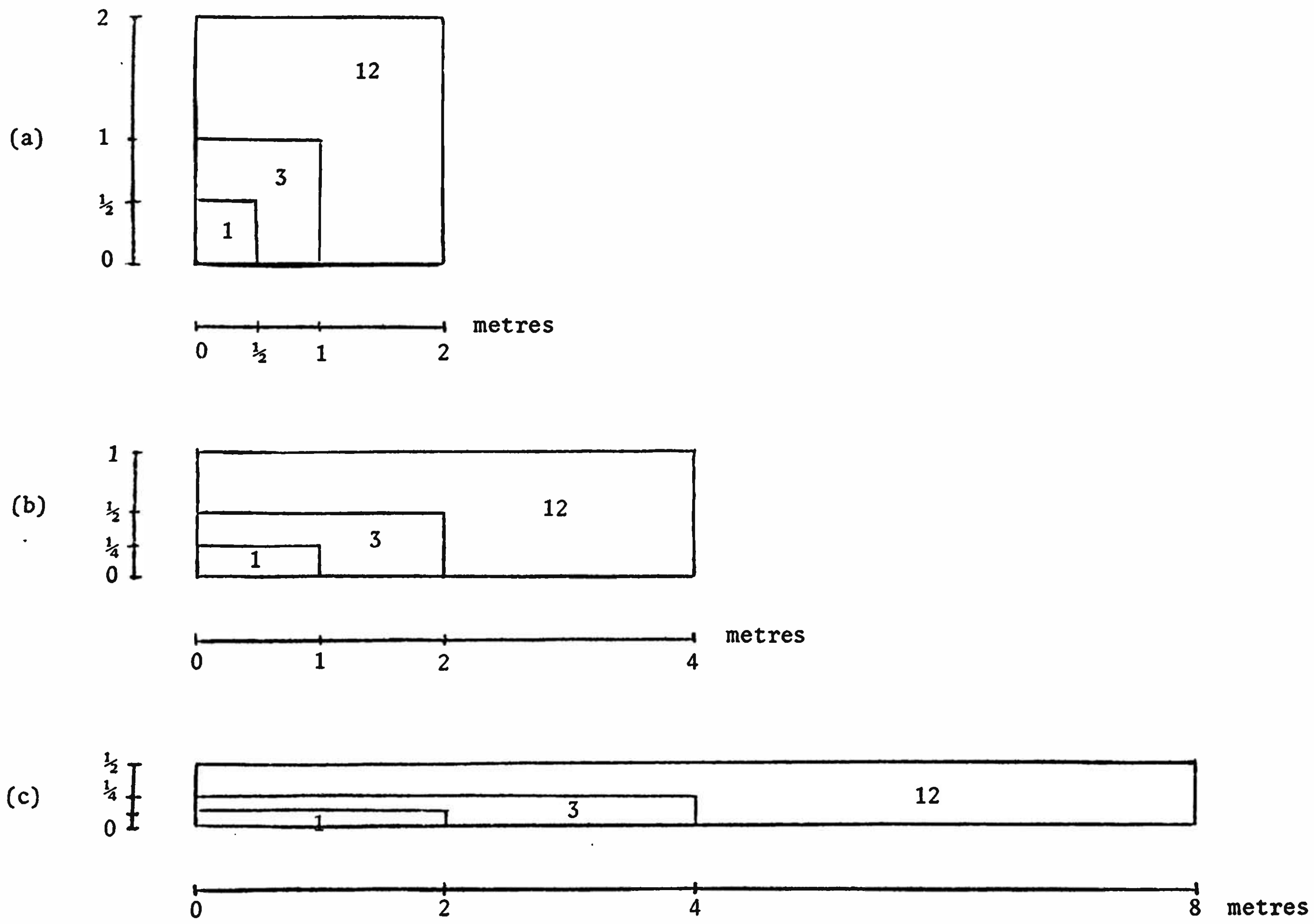

FIGURE 1. The arrangement of each of the three sets of quadrats (a), (b) and (c). Area 1 is 0.25 square metres, area 3 is 0.75 square metres and area 12 is 3.00 square metres in each set. The ratios of the lengths of the quadrat sides are (a) 1:1, (b) 1:4 and (c) 1:16.

QUADRAT		GREEN			DRY			LITTER		
Shape	Size (m^2)	Mean weight (g./sq.m.)	Variance of mean weight (per sq.m.)	Mean time (min.)	Mean weight (g./sq.m.)	Variance of mean weight (per sq.m.)	Mean time (min.)	Mean weight (g./sq.m.)	Variance of mean weight (per sq.m.)	Mean time (min.)
1:1	1(0.25)	27.6	272	47	153	6480	47	73.6	3584	8
	3(0.75)	31.2	126	102	146	2741	102	60.7	1568	11
	4(1.00)	30.3	88	149	148	2155	149	64.0	1757	12
	12(3.00)	27.3	94	415	149	523	415	60.8	718	20
	16(4.00)	28.0	81	562	149	668	562	61.6	831	23
1:4	1(0.25)	22.8	160	35	124	2080	35	64.8	1984	8
	3(0.75)	31.2	325	113	151	1579	113	74.9	1998	12
	4(1.00)	29.1	241	148	146	1471	148	72.5	1898	13
	12(3.00)	26.4	61	418	157	1247	418	53.4	524	18
	16(4.00)	27.1	75	566	154	1115	566	58.2	541	22
1:16	1(0.25)	26.8	336	40	144	5184	40	48.0	416	8
	3(0.75)	27.7	211	115	153	1520	115	57.7	693	12
	4(1.00)	27.5	148	155	151	1656	155	55.3	475	12
	12(3.00)	39.6*	1537*	394	143	1495	394	60.8	344	19
	16(4.00)	36.6*	864*	549	145	1241	549	59.4	276	22

* These values are excessively high due to the erroneous inclusion of a large woody - stemmed Composite.

TABLE 1. The mean weight per square metre, variance per square metre of the mean weight (V) and mean time taken for processing, or cost, (t), for green standing material, dry standing material and litter.

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quate indication that t and V were in fact not correlated and hence that minimising t.V was legitimate.

The product t.V represents the variance which would be expected for a sample which took unit time to collect and therefore amounts to an estimate of variance. A variance ratio test for significant difference is consequently appropriate. Assuming that the distribution of the ratio of two t.V products, i.e. $(t_x.V_x) / (t_y.V_y)$, is log normally distributed, an approximate test for a significant difference took the form:

$$\ln (t_x.V_x) - \ln (t_y.V_y)$$

which is equivalent to ln (F/2). If the difference exceeded 2.04, it was significant at the .05 level of probability.

The values of ln t.V are given in Table 2. The only significant differences within the one shape class are between size 1 and size 16 for dry standing material from quadrat shape 1:4 and between size 1 and sizes 12 and 16 for green standing material from quadrat shape 1:16. The latter difference is due however to an artificially high value of V for sizes 12 and 16 (see footnote Table 1) and must be discounted. The only significant differences within the one size class are between quadrat shape 1:1 and shape 1:16 for litter from a quadrat of size 1 and between quadrat shapes 1:1 and 1:4 and shape 1:16 for green standing material from quadrats of both size 12 and size 16. The differences for green standing material are due to the same artifact mentioned above and should also be discounted.

QUADRAT		GREEN	DRY	LITTER
Shape	Size ($m.^2$)		ln (t.V)	
1:1	1(0.25)	9.46	12.63	10.26
	3(0.75)	9.46	12.54	9.76
	4(1.00)	9.48	12.68	9.96
	12(3.00)	10.57	12.29	9.57
	16(4.00)	10.73	12.84	9.65
1:4	1(0.25)	8.63	11.20	9.67
	3(0.75)	10.51	12.09	10.09
	4(1.00)	10.48	12.29	10.11
	12(3.00)	10.15	13.16	9.15
	16(4.00)	10.66	13.36	9.38
1:16	1(0.25)	9.51	12.24	8.11
	3(0.75)	10.10	12.07	9.03
	4(1.00)	10.04	12.46	8.65
	12(3.00)	13.31*	13.29	8.79
	16(4.00)	13.07*	13.43	8.71

* See footnote table 1.

TABLE 2. The natural logarithm of t.V, where t is the mean time (min.) taken for processing, or cost, and V is the variance of the mean weight (per sq.m.) for green standing material, dry standing material and litter. Differences of 2.04 or more between values indicate a significant difference at the .05 level of probability.

The results suggest that a small sized quadrat may be preferable and that an elongate shape of quadrat is advantageous for litter but unimportant for green or dry standing material. When vegetation is homogeneous, a square quadrat satisfactorily encompasses its pattern of distribution, if the quadrat is an adequate size. But when the vegetation is heterogeneous, an elongate shape of quadrat will incorporate the variability far better. The pattern of distribution is complex in arid vegetation and, coupled with increasing total variance as sampling area is increased, a continuum of vegetational change is likely (Goodall 1961). It was thus expected that the elongate shape would confer some advantage but it did so for litter only. An analysis of variance did not detect any significant difference between mean weights of each category of vegetation for quadrats of the same area but of different shape. The absence of bias shows that there was no edge effect.

Small quadrat size was expected to be preferable because statistically the smaller the sampling unit, the more efficient it is per unit area (Pechanec and Stewart 1940). The trend of results indicates that this may be so for green and dry standing material but that for litter, the quadrat size is not important.

The number of quadrats selected depends on the nature of the work in which they will be used. The calculation takes this form: see Bell [illegible]

$$n = \frac{4\sigma^2}{L^2}$$

where n is the number of quadrats, σ^2 is the variance and L is the allowable error in the sample mean with a 5% chance that the error will exceed L (Snedecor 1957). Almost invariably, the time taken to process the number of quadrats will limit the value to which L can be reduced.

The results presented here suggest that, for the area sampled, the quadrat chosen would be of 1 square metre or less and of a shape that was most convenient to the user. A quadrat of considerably less that 1 square metre may not be desirable on other grounds not considered here, for instance for financial reasons, since the smaller the quadrat the greater the number of quadrats required to compensate for increased variance per unit area, and hence the greater the cost of markers.

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