Determining Sampling Adequacy & Appropriate Quadrat Size for Sampling
Exercise 12

The objective of this exercise will be to consider the influence of quadrat size on sampling efficiency. This question will require you to consider the impact of sample set variation, the time required to collect an adequate sample and the degrees of freedom associated with that data set. For example, quadrats that are too small to represent a populations spatial structure will contribute empty plots to your data set and increase sample set variation. Quadrats that are too large will require greater amounts of time to read which yield a diminishing return in terms of information gain per unit of time and sample sets with too few samples create issues in sampling sufficiency that are expressed in low degrees of freedom which reduce the sensitivity of data set comparisons.

In this exercise we will be using production (methodology described in exercise 4) estimates from a grassland community. The production values are reported in grams of oven-dry biomass/quadrat from an ecological site that would be expected to yield approximately 1100 kgDM/ha (1000 lbsDM/acre). The data was collected through a random sampling of the community using a nested quadrat design (Figure 1) which contained 0.1, 0.5 and 1.0 m^2 quadrat sizes.

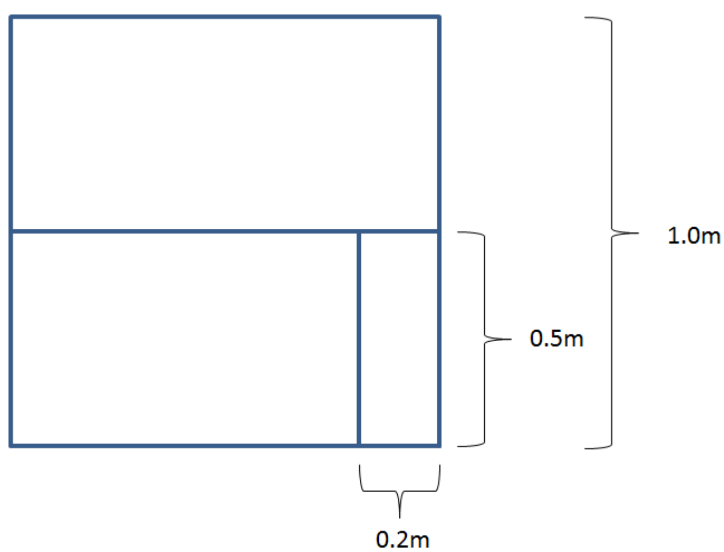

Figure 1. Nested quadrat identifying 1m^2, 0.5m^2, and 0.1m^2 quadrats on the ground for sampling plant above-ground biomass.

The quadrat frame is typically made out of metal so that it is rigid enough to be durable and maintain its shape but light enough to be easily carried.

A preliminary sampling yields the following data set which we will assess for quadrat efficiency.

Quadrat Size	**0.1m²**	**0.5m²**	**1.0m²**
Sample Number	**Grams**	**Grams**	**Grams**
1	12	58	126
2	16	48	90
3	8	46	84
4	11	54	140
5	10	44	100
6	9	48	60
7	11	48	102
8	11	48	126
9	13	54	116
10	10	44	94
11	6	36	88

A summary of the data yields the following statistics:

Quadrat Size	0.1m²	0.5m²	1.0m²
Sample Size	11	11	11
Mean (grams)	10.6	48	102.4
Production	1060 kg/ha, 943 lbs/a	960 kg/ha, 854 lbs/a	1020 kg/ha, 911 lbs/a
Std. Dev.	2.61	5.65	21.92
Variance	6.85	31.92	480.48

Step One: To compare the variability contained in different sized quadrats (0.1, 0.5 and 1.0m^2) the variability needs to be standardized. Standardization will be accomplished by calculating the Coefficient of Variation (CV) for each data set. The CV is calculated as a ratio of the standard deviation to the mean and is reported as a percent. The expression of quadrat variability on a relative basis permits the comparison of the different plot sizes.

Quadrat Size	0.1m²	0.5m²	1.0m²
Coef. Of Variation (%)	24.6	11.6	21.4

A visual inspection of the CV values indicates that the 0.5m^2 data set contains the least amount of variation relative to its mean estimate. Thus, we can anticipate from the CV that the 0.5m^2 plot size will require the least number of samples to achieve a desired level certainty for the mean estimate.

Step Two: A Stein's Two Stage Procedure (1945 Charles Stein, Columbia University) is a calculation of sample adequacy is made to determine the number of samples that would be required to achieve a mean estimate within a specified level of error and a given level of confidence. The Procedure uses the Student's t distribution along with an initial estimation of the variance of the parameter being measured to estimate the population mean with a specific level of accuracy and precision. The sample adequacy equation is:

$$n = \frac{(t^2 s^2)}{E^2}$$

Where: n = sample size

t = T table value with n-1 degrees of freedom (Sample set)

S^2 = Variance of the sample set

E = The level of error specified for the mean estimate = ((Sample Set Mean)(% error)).

In our example, we will set the desired level of error for the mean estimate at 10% with a corresponding 90% level of confidence. Thus we will be 90% sure that the mean value we obtain is within 10% of the true mean.

Quadrat Size	**0.1m²**	**0.5m²**	**1.0m²**
Sample Adequacy (sample size)	20	5	15

A visual inspection of the sample size (sample adequacy) estimates indicates that the 0.5m² plot size requires the fewest number of samples to achieve a mean estimate that is within 10% of the actual (population) value with 90% confidence. This answer corroborates our assessment based on the CV. However, our assessment of quadrat efficiency has not considered the amount of time required to achieve the adequate sample.

Step Three: At the time of the preliminary data collection we recorded the amount of time required to collect the production data for each quadrat. This information was summarized and yielded an estimate of average time per quadrat.

Quadrat Size	**0.1m²**	**0.5m²**	**1.0m²**
Time/plot (Minutes)	2	10	18
Adequate Sample Size	20	5	15
Time/Adequate Sample	40 minutes	50 minutes	270 minutes

A visual comparison of this information shows that the 0.1 and the 0.5m² quadrat sizes yield similar time commitments to achieve sample adequacy and that the 1.0m² quadrat requires at least 5 times more time to gain the same amount of information. Obviously the 1.0m² quadrat is sampling too much area to be efficient in this community.

Step Four: To separate the sufficiency of the 0.1 and 0.5m^2 quadrats in subsequent statistical analyses we turn to the t-table to make a general assessment of the impact of 19 degrees of freedom (0.1m^2) compared to 4 degrees of freedom (0.5m^2). The t-distribution is used to estimate the deviation of an estimated mean from the true mean. Its value is influenced by the degrees of freedom contained in the population estimate in that a larger t value signifies less sensitivity for determining difference. In this case the t values are 1.729 (0.1m^2) and 2.132 (0.5m^2). The difference between a sample size of 20 versus 5 will result in a 23% increase in the t value and a loss in testing sensitivity for the 0.5m^2 quadrat.

The conclusion drawn from this set of comparisons is that we should use the 0.1m^2 plot for future production data collection in this population.

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Critical values of Student's *t* distribution with *v* degrees of freedom

(Table Courtesy of National Institute of Standards and Technology (NIST))

Given a specified value for α :

1. For a two-sided test, find the column corresponding to 1-α/2 and reject the null hypothesis if the absolute value of the test statistic is greater than the value of $t_{1-\alpha/2,v}$ in the table below.
2. For an upper, one-sided test, find the column corresponding to 1-α and reject the null hypothesis if the test statistic is greater than the table value.
3. For a lower, one-sided test, find the column corresponding to 1-α and reject the null hypothesis if the test statistic is less than the negative of the table value.

Probability less than the critical value ($t_{1-\alpha,v}$)

ν	0.90	0.95	0.975	0.99	0.995	0.999
1.	3.078	6.314	12.706	31.821	63.657	318.313
2.	1.886	2.920	4.303	6.965	9.925	22.327
3.	1.638	2.353	3.182	4.541	5.841	10.215
4.	1.533	2.132	2.776	3.747	4.604	7.173
5.	1.476	2.015	2.571	3.365	4.032	5.893
6.	1.440	1.943	2.447	3.143	3.707	5.208
7.	1.415	1.895	2.365	2.998	3.499	4.782
8.	1.397	1.860	2.306	2.896	3.355	4.499
9.	1.383	1.833	2.262	2.821	3.250	4.296
10.	1.372	1.812	2.228	2.764	3.169	4.143
11.	1.363	1.796	2.201	2.718	3.106	4.024
12.	1.356	1.782	2.179	2.681	3.055	3.929
13.	1.350	1.771	2.160	2.650	3.012	3.852
14.	1.345	1.761	2.145	2.624	2.977	3.787
15.	1.341	1.753	2.131	2.602	2.947	3.733
16.	1.337	1.746	2.120	2.583	2.921	3.686
17.	1.333	1.740	2.110	2.567	2.898	3.646
18.	1.330	1.734	2.101	2.552	2.878	3.610
19.	1.328	1.729	2.093	2.539	2.861	3.579
20.	1.325	1.725	2.086	2.528	2.845	3.552
21.	1.323	1.721	2.080	2.518	2.831	3.527
22.	1.321	1.717	2.074	2.508	2.819	3.505
23.	1.319	1.714	2.069	2.500	2.807	3.485
24.	1.318	1.711	2.064	2.492	2.797	3.467
25.	1.316	1.708	2.060	2.485	2.787	3.450
26.	1.315	1.706	2.056	2.479	2.779	3.435
27.	1.314	1.703	2.052	2.473	2.771	3.421
28.	1.313	1.701	2.048	2.467	2.763	3.408
29.	1.311	1.699	2.045	2.462	2.756	3.396
30.	1.310	1.697	2.042	2.457	2.750	3.385
31.	1.309	1.696	2.040	2.453	2.744	3.375
32.	1.309	1.694	2.037	2.449	2.738	3.365
33.	1.308	1.692	2.035	2.445	2.733	3.356
34.	1.307	1.691	2.032	2.441	2.728	3.348
35.	1.306	1.690	2.030	2.438	2.724	3.340
36.	1.306	1.688	2.028	2.434	2.719	3.333
37.	1.305	1.687	2.026	2.431	2.715	3.326
38.	1.304	1.686	2.024	2.429	2.712	3.319
39.	1.304	1.685	2.023	2.426	2.708	3.313
40.	1.303	1.684	2.021	2.423	2.704	3.307
∞	1.282	1.645	1.960	2.326	2.576	3.090