

Instructions on Using the Sample Size and Power Workbook to Calculate Sample Sizes and Power for Several Different Sampling Situations

The Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) includes procedures to calculate sample size for six different sampling situations. For those four sampling situations that involve the comparison of two means or proportions, the workbook also calculates statistical power and minimum detectable change.

Each of the six procedures is on worksheets 2-7. Worksheet 1, *Intro*, contains a selectable menu which can be used to navigate to the appropriate worksheet.

Five of the six procedures correspond to the five sample size equations provided in Appendix 7 of Measuring and Monitoring Plant Populations (Elzinga et al. 1998):

Equation 1: Estimate a single population mean with a specified confidence interval width.

Equation 2: Differences between two means with temporary sampling units.

Equation 3: Differences between two means with permanent/paired sampling units.

Equation 4: Estimate a single proportion with a specified confidence interval width.

Equation 5: Differences between two proportions with temporary sampling units.

A sixth procedure, calculating the necessary sample size when comparing the estimate of a mean to a threshold value, is also included in the workbook. The procedure provides a method of assessing whether a threshold management objective has been met (see Elzinga et al. 1998, page 46, for a discussion of a threshold management objective). One way to accomplish this (and the way recommended in Elzinga et al. 1998) is to plot the estimated mean and confidence interval and see whether the confidence interval includes the threshold value. For this, Equation 1 suffices. An alternative method is to conduct a one-sample t test, comparing the sample mean to the threshold value. That is what the sixth procedure does. That procedure is discussed last (sixth) here, even though it is the second procedure listed on the Introduction worksheet of the Excel workbook.

This workbook was originally created in an older version of Excel as a *.xls file. It has been converted to an *.xlsm file (the current Excel macro-enabled workbook file type) and works in Excel 365. It likely also works in earlier versions of Excel from 2007 on, but it has not been tested using those versions.

Please also note the following disclaimer:

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

The workbook was originally developed by Sound Science LLC with input from Dan Salzer. The current version has been edited and updated by Dan Salzer and John Willoughby. These instructions were authored by Dan Salzer and John Willoughby.

Literature Cited

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Technical Reference 1730-1. U.S. Department of the Interior, Bureau of Land Management, Denver, CO.

Equation 1: Single population mean with a specified confidence interval width

Using the Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) to calculate the sample size needed to estimate a single population mean or a single population total with a specified confidence interval width.

The sample size needed to estimate confidence intervals that are within a given percentage of the estimated *total population size* is the same as the sample size needed to estimate confidence intervals that are within that percentage of the sample *mean value*. The instructions below assume you are working with a sample mean.

1. Open the file “Sample Size and Power Workbook 2020.xlsm” in Microsoft Excel.
2. Make sure to enable macros.
3. Choose “Single Sample” from the menu. This takes you to the “Single Sample CI” worksheet.
4. Enter the desired confidence level (e.g., 90%, 95%) in Cell J6.
5. Enter the desired confidence interval width. You can either enter the confidence interval width as a percentage of the mean in Cell J8 or the absolute confidence interval width in Cell J9. Note that for whichever option you choose this is half of the total confidence interval length. For example, if you enter 20 in Cell 9 as the desired absolute confidence interval width, this corresponds to an estimated mean ± 20 , which is half the length of the total confidence interval length of 40.
6. Enter the tolerance probability in Cell J10. Because the simple sample size formula for estimated a single mean underestimates the actual sample size needed, a correction developed by Kupper and Hafner (1989) is required. Enter the same probability here as the confidence level entered in Cell J6. For example, if you entered 95% in Cell J6, enter 0.95 in Cell J10.
7. If you’re sampling from a finite population (i.e., you’re using quadrats), enter the total population area in Cell J13 and the area of a single quadrat in Cell J14. This will apply the finite population correction to your estimated sample size. If you’re sampling from an infinite population (e.g., you’re estimating cover by point intercepts and you’re treating transects of points as the sampling units), leave Cells J13 and J14 blank.
8. Enter the number of sampling units (n) from the pilot sample in Cell J21.
9. Enter the sample mean in Cell J22.
10. Enter the sample standard deviation in Cell J23.
11. If you’ve sampled from a finite population, the sample size is given in Cell J39. Round this number up to the next whole integer. For example, if Cell J39 shows 31.2, the sample size to use is 32. If you’ve sampled from an infinite population use the sample

Equation 1: Single population mean with a specified confidence interval width

size given in Cell J37 and round up to the next whole interval. (Note: if Cells J13 and J14 were left blank, Cells J37 and J39 will give the same sample size.)

Example: This example is the same as that used in MMPP, Appendix 7, Sample Size Equation #1. Our sampling objective is to estimate the mean density of species Y in population Z and to be 95% confident that this estimate is within 20% of the estimated mean density. From our pilot sampling ($n=10$) we've calculated a mean of 25 plants/quadrat and a standard deviation of 7 plants/quadrat. The pilot data were collected in a sample of 10 quadrats, each 1m x 10m (10m^2) in size, within a 20m x 50m macroplot (1000m^2). Here is how we'd enter these data into the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

4. Enter 95% in Cell J6.
5. Enter 20% in Cell J8 and leave Cell J9 blank. Alternatively, you could enter the absolute confidence interval width ($20\% \times 25 = 5$) in Cell J9 and leave Cell J8 blank.
6. Enter 0.95 (same as the confidence level) in Cell J10.
7. Enter 1000 (the total population area) in Cell J13 and enter 10 (the area of a single quadrat) in Cell J14.
8. Enter 10 (the pilot sample size) in Cell J21.
9. Enter 25 (the sample mean) in Cell J22.
10. Enter 7 (the sample standard deviation) in Cell J23.
11. Read the sample size in Cell J39. Round this number (13.1) up to the next whole integer (14).

Literature Cited

Kupper, L. L., and K. B. Hafner. 1989. How appropriate are popular sample size formulas? *The American Statistician* 43:101-105.

Equation 2: Differences between two means with temporary sampling units

Using the Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) to calculate the sample size needed to detect differences between two means with temporary sampling units.

1. Open the file “Sample Size and Power Workbook 2020.xlsm” in Microsoft Excel.
2. Make sure to enable macros.
3. Choose “Temporary Plots” from the menu. This takes you to the “Two means -- temporary” worksheet.
4. Enter the desired power (e.g., 0.80, 0.90) in Cell J6.
5. Specify a 1-sided or 2-sided test in cell J8
6. Enter the acceptable false-change error rate (e.g., 0.10, 0.20) in Cell J7.
7. Enter the targeted minimum detectable change (MDC). You can either enter the MDC as a percentage of the mean in Cell J11 or as an absolute value in Cell J12. It is generally better to enter the relative value in Cell J11 because it saves you a step. If you decide to enter the absolute value you will need to express it in the same units as your mean. For example, if your pilot mean is 10 plants/ quadrat and you want to detect a 20% change, you would enter $10 \times 20\%$ or 2 in Cell J12. Whichever option you choose be sure to leave the other cell blank (i.e., if you enter the relative percent value in Cell J11 leave Cell J12 blank, or if you enter the absolute difference in Cell J12, leave Cell J11 blank).
8. If you’re sampling from a finite population (i.e., you’re using quadrats), enter the total population area in Cell J15 and the area of a single quadrat in Cell J16. This will apply the finite population correction to your estimated sample size. If you’re sampling from an infinite population (e.g., you’re estimating cover by point intercepts and you’re treating transects of points as the sampling units) leave Cells J15 and J16 blank.
9. Enter the number of sampling units (n) from your pilot sample in Cell J23.
10. Enter the sample mean from your pilot sample in Cell J24.
11. Enter the sample standard deviation from your pilot sample in Cell J25.
12. If you’ve sampled from a finite population, the sample size is given in Cell J41. Round this number up to the next whole integer. For example, if Cell J41 shows 31.2, the sample size to use is 32. If you’ve sampled from an infinite population use the sample size given in Cell J39 and round up to the next whole interval. (Note: if Cells J15 and J16 were left blank, Cells J39 and J41 will give the same sample size.)
13. The worksheet gives you other information on your pilot sample, including confidence intervals for both the mean (Cells J29-J31) and total population (Cells J32-J33), and how well your sample performed in terms of MDC and power (Cells J45 and Cell J47).

Example: This example is the same as that used in MMPP, Appendix 7, Sample Size Equation #2. Our management objective is to increase the density of Species F at Site Y by 20% over the

Equation 2: Differences between two means with temporary sampling units

next 5 years. Our sampling objective is be 90% certain of detecting a 20% change in mean plant density and we're willing to accept a 10% chance of making a false-change error (concluding that a change took place when it really did not. From our pilot sampling ($n=10$) we've calculated a mean of 25 plants/quadrat and a standard deviation of 7 plants/quadrat. The pilot data were collected in a sample of 10 quadrats, each 1m x 10m (10m^2) in size, within a 20m x 50m macroplot (1000m^2). Here is how we'd enter these data into the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

4. Enter 0.90 in Cell J6. This corresponds to our desired 90% power.
5. Enter 0.10 in Cell J7. This is the acceptable false-change error rate.
6. Enter 2 for 2-sided test in cell J8
7. Enter 20% in Cell J11 and leave Cell J12 blank. This is the minimum detectable change as specified in our sampling objective (we want to "detect a 20% change in mean plant density").
8. Enter 1000 (the total population area) in Cell J15, and enter 10 (the area of a single quadrat) in Cell J16.
9. Enter 10 (the pilot sample size) in Cell J23.
10. Enter 25 (the sample mean) in Cell J24.
11. Enter 7 (the sample standard deviation) in Cell J25.
12. Read the sample size in Cell J41. Round this number (25.6) up to the next whole integer (26).
13. The worksheet gives you other information on your pilot sample, including confidence intervals for both the mean (Cells J29-J31) and total population (Cells J32-J34), and how well your sample performed in terms of MDC and power (Cells J45 and Cell J47).

Equation 3: Differences between two means with permanent/paired sampling units

Using the Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) to calculate the sample size needed to detect differences between two means with permanent or paired sampling units.

1. Open the file “Sample Size and Power Workbook 2020.xlsm” in Microsoft Excel.
2. Make sure to enable macros.
3. Choose “Permanent Plots” from the menu. This takes you to the “Two means -- permanent” worksheet.
4. Enter the desired power (e.g., 0.80, 0.90) in Cell J6.
5. Enter the acceptable false-change error rate (e.g., 0.10, 0.20) in Cell J7.
6. Enter 1 or 2 for 1-sided or 2-sided test in Cell J8.
7. Enter the targeted minimum detectable change (MDC). You can either enter the MDC as a percentage of the mean in Cell J11 or as an absolute value in Cell J12. It is generally better to enter the relative value in Cell J11 because it saves you a step. If you decide to enter the absolute value you will need to express it in the same units as your mean. For example, if your pilot mean is 10 plants/ quadrat and you want to detect a 20% change, you would enter $10 \times 20\%$ or 2 in Cell J12. Whichever option you choose be sure to leave the other cell blank (i.e., if you enter the relative percent value in Cell J11 leave Cell J12 blank, or if you enter the absolute difference in Cell J12, leave Cell J11 blank).
8. If you’re sampling from a finite population (i.e., you’re using quadrats), enter the total population area in Cell J15 and the area of a single quadrat in Cell J16. This will apply the finite population correction to your estimated sample size. If you’re sampling from an infinite population (e.g., you’re estimating cover along permanent line-intercept transects or point intercept where you’re treating permanent transects of points as the sampling units) leave Cells J15 and J16 blank.
9. Enter the number of sampling units (n) from your pilot sample in Cell J23.
10. Enter either the sample mean from the first year of pilot data OR the observed mean difference between two years (or pairs) of pilot data in Cell J24.
11. Enter either the sample standard deviation from the first year of pilot data OR the standard deviation of the differences observed between two years (or pairs) of pilot data in Cell J25.
12. If your pilot data is from the first year of data only, enter a 1 in cell J26 and estimate the likely degree of correlation (a decimal value between 0 and 1) between two years of data in cell J28 (e.g., for example, enter 0.90 if you think sampling unit values would be highly correlated between two years of data).
13. If you have pilot data from two years (or pairs) of data, enter a 2 in cell J26. If the MDC was specified as a relative value in Cell J11, then enter the mean value to use as the

Equation 3: Differences between two means with permanent/paired sampling units

basis for applying a relative MDC in Cell J29. If you specified the MDC in absolute measurement units in Cell J12, then leave Cell J29 blank.

14. If you've sampled from a finite population, the sample size is given in Cell J42. Round this number up to the next whole integer. For example, if Cell J42 shows 31.2, the sample size to use is 32. If you've sampled from an infinite population use the sample size given in Cell J40 and round up to the next whole interval. (Note: if Cells J15 and J16 were left blank, Cells J40 and J42 will give the same sample size.)
15. The worksheet gives you other information about your pilot sample, including confidence intervals around the mean (or mean difference - Cells J33-J35) and how well your sample performed in terms of MDC and power (Cells J46 and Cell J48).

Example #1: This example is the same Example #1 that is used in MMPP, Appendix 7, Sample Size Equation #3. Our management objective is to achieve at least a 20% higher density of species F at site Y in areas excluded from grazing as compared to grazed areas in 1999. Our sampling objective is to be able to detect a 20% difference in mean plant density in areas excluded from grazing and adjacent paired grazed areas. We want to be 90% certain of detecting that difference, if it occurs, and we are willing to accept a 10% chance that we will make a false-change error (conclude that a difference exists when it really did not).

Five paired quadrats were sampled where one member of the pair was excluded from grazing (with a small enclosure) and the other member of the pair was open to grazing.

Quadrat number	# of plants/quadrat		Difference between grazed and ungrazed
	grazed	ungrazed	
1	2	3	1
2	5	8	3
3	4	9	5
4	7	12	5
5	3	7	4
	mean= 4.20 s =1.92	Mean = 7.80 s=3.27	
Summary statistics for the differences between the two sets of quadrats			Mean = 3.60 s = 1.67

The pilot data were collected in a sample of quadrats 1m x 10m (10m²) in size, within a 10m x 50m macroplot (500m²). Here is how we'd enter these data into the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

4. Enter 0.90 in Cell J6. This corresponds to our desired 90% power.
5. Enter 0.10 in Cell J7. This is the acceptable false-change error rate.

Equation 3: Differences between two means with permanent/paired sampling units

6. Enter 2 for 2-sided test in cell J8.
7. Enter 20% in Cell J1 and leave Cell J12 blank. This is the minimum detectable change as specified in our sampling objective (we want to “detect a 20% difference in mean plant density”).
8. Enter 500 (the total population area) in Cell J15, and enter 10 (the area of a single quadrat) in Cell J16.
9. Enter 5 (the pilot sample size) in Cell J23.
10. Enter 3.6 (the mean differences among the quadrats) in Cell J24.
11. Enter 1.67 (the sample standard deviation of the mean differences) in Cell J25.
12. Because we have a set of paired data, we enter a 2 in Cell J26.
13. We enter the larger of the two means (7.80) in Cell J29.
14. Read the sample size in Cell J42. Round this number (8.204) up to the next whole integer (9).
15. The worksheet gives you other information on your pilot sample, including confidence intervals around the mean (or mean difference - Cells J33-J34) and how well your sample performed in terms of MDC and power (Cells J46 and Cell J48).

Example #2: This example is the same Example #1 that is used in MMPP, Appendix 7, Sample Size Equation #3. Our management objective is to increase the density of species F at Site Q by 20% between two years. Our sampling objective is to detect a 20% difference in mean plant density of species F at Site Q between two years. We want to be 90% certain of detecting that change, if it occurs, and we are willing to accept a 10% chance that we will make a false-change error (conclude that a change took place when it really did not).

The procedure for determining the necessary sample size for this example would be very similar to the previous example. Just replace "grazed" and "ungrazed" in the data table with two calendar years and the rest of the calculations would be the same if you have two years of pilot data. If you have a single year of pilot data, enter a 1 in cell J26 and enter a correlation coefficient (between 0 and 1) in cell J28.

Equation 4: Estimate a single proportion with specified confidence interval width

Using the Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) to calculate the sample size needed to estimate a single population proportion with a specified confidence interval width.

Open the file “Sample Size and Power Workbook 2020.xlsm” in Microsoft Excel.

1. Make sure to enable macros.
2. Choose “Frequency CIs” from the menu. This takes you to the “CI for proportion” worksheet.
3. Enter the desired confidence level (e.g., 90%, 95%) in Cell J7.
4. Enter the desired absolute confidence interval width in Cell J9 (Absolute Confidence Interval Width”). This is half of the total confidence interval length. Thus, if you enter 5% in Cell J10 as the desired absolute confidence interval width, this corresponds to an estimated proportion of $\pm 5\%$ (± 0.05), which is half the total confidence interval length of 10%. The absolute confidence interval width is expressed in the same units as the estimated proportion. Thus, if the desired absolute confidence interval width is $\pm 10\%$ and the estimated proportion is 30%, then the confidence interval width is $30\% \pm 10\%$ or 20% to 40%.
5. If you’re sampling from a finite population (i.e., you’re using quadrats), enter the total population area in Cell J12 and the area of a single quadrat in Cell J13. This will apply the finite population correction to your estimated sample size. If you’re sampling from an infinite population (e.g., you’re estimating cover by point intercepts) leave Cells J12 and J13 blank.
6. Enter the number of sampling units (n) from your pilot sample in Cell J17.
7. Enter the estimated proportion from your pilot sample in Cell J18.
8. If you’ve sampled from a finite population, the sample size is given in Cell J24. If you’ve sampled from an infinite population use the sample size given in Cell J22. (Note: if Cells J12 and J13 are left blank, a very large N is put into Cell J14 with the result that Cell J24 returns the same sample size as Cell J22.)

Example 1: This example is the same as that used in MMPP, Appendix 7, Sample Size Equation #4. Our management objective is to maintain at least a 40% frequency (in 1m^2 quadrats) of species Y in population Z over the next 5 years. Our sampling objective is to estimate the percent frequency with 95% confidence intervals no wider than 10% (absolute) of the estimated true value. From our pilot sampling ($n=40$) we’ve estimated the proportion of quadrats with Species Y to be 65% (0.65). The pilot data were collected using a $1\text{m} \times 1\text{m}$ (1m^2) quadrat located within a $25\text{m} \times 25\text{m}$ macroplot (625m^2). Here is how we’d enter these data into the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

Equation 4: Estimate a single proportion with specified confidence interval width

4. Enter 95% in Cell J7.
5. Enter 10% in Cell J9.
6. Enter 625 (the total population area) in Cell J13, and enter 1 (the area of a single quadrat) in Cell J13.
7. Enter 65% in Cell J18. This is our pilot estimate of the frequency of Species Y.
8. Read the sample size in Cell J24. Note that this number (78) is less than the number (88) we would have had to sample had we been sampling from an infinite population. This results from the fact that if we'd sampled the 88 quadrats (area=88m²) required for an infinite population from this 625m² population we'd have sampled 88/625=14% of the population. As a "reward" for sampling this much of the population, the finite population correction factor reduces the required sample size to 78 quadrats.

Example 2: In the second example our management objective is to ensure the total cover of all shrubs at Site X does not exceed 40% over the next 10 years. Our sampling objective is to be 90% confident that our estimate of cover is within $\pm 5\%$ (absolute) of the estimated true cover. We conduct a pilot study in a 50m x 100m macroplot using 50 point intercepts and treat the points as the sampling units. Our pilot estimate of the cover of shrubs is 32%. Here is how we'd enter these data in the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4.

4. Enter 90% in Cell J7.
5. Enter 5% in Cell J9.
6. Leave Cells J12 and J13 blank. Because there are an infinite number of points that can be placed in a macroplot of any size, we are unable to take advantage of the finite population correction factor.
7. Enter 50 in Cell J17. This is our pilot sample size (*for reference purposes only – not used in sample size calculations*).
8. Enter 32% in Cell J18. This is our pilot estimate of the cover of shrubs.
9. Read the sample size (236) in Cell J23. Note that Cell J25 (FPC Sample Size) returns the same value because the value in Cell 14 (big N) is large enough to be effectively infinite.

Notes on the sample size output from this procedure.

This worksheet implements Sample Size Equation #4 on page 358 of *Measuring and Monitoring Plant Populations*. Because this equation uses the normal approximation, it is known to give sample size estimates that are somewhat lower than those required to achieve the objective confidence interval width at the confidence level chosen. A more conservative approach uses an exact procedure described in Zar (1996, pp. 524-526). This procedure is implemented in the commercial software program PASS (Power and Sample Size), where the procedure is referred to as the Clopper and Pearson procedure (from a paper by Clopper and Pearson, 1934). In

Equation 4: Estimate a single proportion with specified confidence interval width

general, the number of additional sampling units required by the Clopper and Pearson procedure, compared to the procedure in the worksheet, increases as the size of the desired absolute confidence interval decreases, regardless of the confidence level chosen. For example, if your desired absolute confidence interval width is $\pm 10\%$, you would need between 7-10 additional sampling units (the larger number when you are near 0% or 100%, the smaller number when near 50%). If your desired absolute confidence interval width is $\pm 5\%$, you would need between 17-20 additional sampling units. These additional sampling units are based on the situation in which you're sampling from an infinite population and would be somewhat lower if you instead sample from a finite population (and sample more than 5% of the population).

Instead of purchasing the program PASS, there is another option to improve the performance of the sample size estimates in the Sound Science worksheet. You can calculate sample size using the Sound Science worksheet and then refer to the Excel workbook, **CIs-Proportion.xlsm**, provided to you on the course CD, which uses the same exact approach discussed by Zar and implemented in PASS. Input the following into CIs-Proportion.xlsm:

In Cell H10: the sample size estimate from the Sound Science worksheet.

In Cell H11: the appropriate value of alpha for the confidence level used in the Sound Science worksheet (e.g., for a 90% confidence level, input 0.1).

In Cell H14: the number of quadrats in the population (assuming you used quadrats and not points). If you used points leave cell H13 blank.

Now scroll down the CIs-Proportion.xlsm worksheet and see whether the confidence intervals given for your sample proportion meet your objectives. If not, add some number of sampling units (say 10) to the number in Cell H9 and look again. Using this process you should be able to arrive at a more conservative estimate of the sample size.

For more information on different methods for calculating sample size for confidence intervals around a single proportion, see Newcombe (1998).

Literature Cited

Clopper, C. J. and Pearson, E. S. 1934. The use of confidence or fiducial limits illustrated in the case of the binomial. *Biometrika* 26: 404-413.

Newcombe, R. G. 1998. Two-sided confidence intervals for the single proportion: comparison of seven methods. *Statistics in Medicine* 17: 857-872.

Zar, J. H. 1996. *Biostatistical analysis*, 3rd ed. Prentice Hall, Upper Saddle River, New Jersey.

Equation 5: Differences between two proportions with temporary sampling units

Using the Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) to calculate the sample size needed to detect differences between two proportions with temporary sampling units.

1. Open the file “Sample Size and Power Workbook 2020.xlsm” in Microsoft Excel.
2. Make sure to enable macros.
3. Choose “Temporary Freq. Plots” from the menu. This takes you to the “Two proportions -- temporary” worksheet.
4. Enter the desired power (e.g., 0.80, 0.90) in Cell J6.
5. Enter the acceptable false-change error rate (e.g., 0.10, 0.20) in Cell J7.
6. Enter 1 or 2 for 1-sided or 2-sided test in cell C8.
7. If you’re sampling from a finite population (i.e., you’re using quadrats), enter the total population area in Cell J13 and the area of a single quadrat in Cell J14. This will apply the finite population correction to your estimated sample size. If you’re sampling from an infinite population (e.g., you’re estimating cover with point intercepts) leave Cells J13 and J14 blank.
8. Enter the number of sampling units (n) from your pilot sample in Cell J18 (*for reference purposes only – not used in sample size calculations*).
9. Enter the proportion (i.e., percent frequency or percent cover from point-intercept sampling) as a percentage value (e.g., 60%) from your pilot sample in cell J19.
10. Enter a second proportion that represents a second year frequency or point-intercept cover value based on your desired minimum detectable change in cell J20. For example, if your first year frequency value is 50% and you want to be able to detect a 20% absolute change in frequency, you should enter either 30% or 70% as the second proportion. The reason absolute terms are used instead of relative terms relates to the type of data being gathered (percent frequency is already expressed as a relative measure).
 - If your pilot sample frequency value is < 50%, enter a second proportion that represents your pilot sample frequency **plus** the minimum detectable change size. For example, if your minimum detectable change is an absolute change of 25% and your first year frequency value is 40%, enter 65% as the second proportion.
 - If your pilot sample frequency value is > 50%, enter a second proportion that represents your pilot sample frequency **minus** the minimum detectable change size. For example, if your minimum detectable change is an absolute change of 15% and your first year frequency value is 60%, enter 45% as the second proportion.

Equation 5: Differences between two proportions with temporary sampling units

- If you don't have any pilot sampling data, enter 50% in Cell J19 as sample sizes will be highest at this frequency value so it provides a conservative basis for achieving the necessary sample size.
11. The worksheet provides sample size estimates using the Snedecor and Cochran method (Snedecor and Cochran 1980, page 129). Cell J26 gives the sample size with the finite population correction. Cell J25 provides the sample size without the finite population correction.

Example:

This example is the same example that is used in MMPP, Appendix 7, Sample Size Equation #5. Our management objective is to decrease the frequency of invasive weed F at Site G by 20% between two years. Our sampling objective is be 90% certain of detecting an absolute change of 20% frequency and be willing to accept a 10% chance of making a false-change error (conclude that a change took place when it really did not). The proportion of quadrats with weed F in the first year is 65%. The pilot frequency data was gathered using 100 1m x 1m (1 m²) quadrats and the total population being sampled was located within a 10m x 30m macroplot (300 m²).

Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

4. Enter 0.90 in Cell J6. This corresponds to our desired 90% power.
5. Enter 0.10 in Cell J7. This is the acceptable false-change error rate.
6. Enter 300 (the total population area) in Cell J13, and enter 1 (the area of a single quadrat) in Cell J14.
7. Enter 100 in Cell J18 (or leave blank - the pilot sample size is not used in the calculations here)
8. Enter 65% in Cell J9
9. Enter 45% in Cell J20. This represents a 20% absolute change in frequency from our first year of data (65% - 20% [MDC] = 45%).
10. Read the sample size in Cell J29 (n=77).

Literature Cited

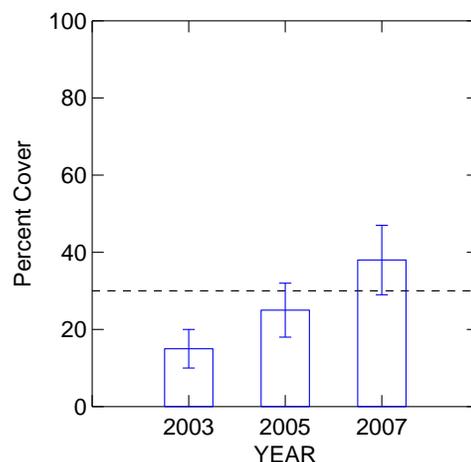
Snedecor, G. W., and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State University Press, Ames, Iowa.

Procedure 6: Comparing a single population mean to a threshold

Using the Sample Size and Power Workbook (“Sample Size and Power Workbook 2020.xlsm”) to calculate the sample size needed to detect a difference between a mean and a threshold value.

This procedure works only for situations in which you are sampling to estimate the mean of a data set consisting of continuous data (e.g., counting plants in quadrats, measuring heights of plants, estimating percent cover in quadrats or using transects of points, estimating frequency where transects of quadrats are the sampling units). It won't work for binomial data (e.g., estimating cover with point intercepts where the points are treated as the sampling units, estimating frequency where quadrats are the sampling units). If your data are binomial, you will need to employ Equation 4, Estimating a Single Proportion with a Specified Confidence Interval Width, in order to compare your population estimate to a threshold value.

The book, *Measuring and Monitoring Plant Populations* (MMPP; Elzinga et al. 1998) does not give an equation for the situation for which this Excel procedure was developed. Instead, MMPP recommends that you use Equation 1 to calculate the sample size needed to estimate a single population mean or a single population total with a specified confidence interval width. This mean (or total) and the confidence interval are then plotted along with a line corresponding to the threshold value, as in the figure below, which shows means and 90% confidence intervals for three separate years. In this situation the threshold for the canopy cover of a weed species has been set at 30%. If the threshold is exceeded, some management action will take place (e.g., herbicide treatment).



We see that in 2003 the threshold was not exceeded by either the sample mean cover or its 90% upper confidence limit. In 2005 the sample mean has increased from 2003. Although the sample mean is still less than the threshold, the upper confidence limit exceeds the threshold, so it is possible that the true population mean has exceeded the threshold. By 2007 the sample

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mean and most of the confidence interval has exceeded the threshold. Even though it is *possible* that the true mean is still below the threshold, we would likely not take that chance and conclude that we have failed to meet the objective.

In this type of analysis it is in our interest to make the confidence intervals as narrow as possible so that situations where the confidence interval straddles the threshold (like in 2005 and 2007 above) are as uncommon as possible given the fact that we're sampling and there will therefore always be some sampling error. Once we determine the confidence level and the width of the confidence interval we're willing to live with, we calculate sample size using Equation 1.

Note, however, that the width of the desired confidence interval is not directly related to the threshold value, whereas the test for which Equation 6 was developed explicitly takes the threshold value into account. A one-sample t test is used to determine if we have crossed the threshold. The test requires us to specify how close to the threshold we're willing to get before concluding the threshold has been crossed. We might, for example, decide that if the estimated mean from our sample is within 5% of the threshold value, we will conclude that the threshold has been crossed. Our sampling objective then specifies a minimum detectable difference of 5% of the threshold value, along with specified power and alpha values (i.e., the same types of information needed to detect changes in two means).

Because our management objective is framed in terms of either keeping something *below* a threshold (like the example above where we will take action if the cover of the weed species reaches or exceeds the threshold) or *above* a threshold value (like might be the case if we're trying to maintain the population of a rare plant above a threshold, a situation we visit in Example 1, below), it makes sense in most situations to use a one-sided test.

With a one-sided test in our weed cover example, our null and alternative hypotheses are as follows:

H_0 : The population mean is essentially the same or greater than the threshold value.

H_A : The population mean is less than the threshold value.

Note that failure to reject the null hypothesis, H_0 , means that we have *not* met our objective. Only if we can show that the population mean is less than the threshold value will we conclude that our objective is met.

If the threshold is a population value, that value needs to be converted to a mean value prior to using the workbook. For example if the threshold is set at a minimum of 5,000 plants and there are $N = 10,000$ possible quadrats in the population, then the threshold population value is

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converted to a mean quadrat value as follows: 5,000 plants/10,000 quadrats = 0.5 plants/quadrat.

Here are the steps involved in using the Compare to Threshold workbook:

1. Open the file "Sample Size and Power Workbook 2020.xlsm" in Microsoft Excel.
2. Make sure to enable macros.
3. Choose "Compare to" from the menu. This takes you to the "Compare to Threshold" worksheet.
4. Enter the desired power (e.g., 0.80, 0.90) in Cell J6.
5. Specify a 1-sided or 2-sided test in cell J8
6. Enter the acceptable false-change error rate (e.g., 0.10, 0.20) in Cell J7.
7. Enter the Minimum Detectable Difference between Sample Mean & Threshold in Cell J10. Note that this is an absolute value. So, for example, if your threshold value is 30 and you will be concerned if you get within 10% of that threshold, you would enter $30 * 10\% = 3$.
8. If you're sampling from a finite population (i.e., you're using quadrats), enter the total population area in Cell J13 and the area of a single quadrat in Cell J14. This will apply the finite population correction to your estimated sample size. If you're sampling from an infinite population (e.g., you're estimating cover by point intercepts and you're treating transects of points as the sampling units) leave Cells J13 and J14 blank.
9. Enter the number of sampling units (n) from your pilot sample in Cell J21.
10. Enter the sample mean from your pilot sample in Cell J22.
11. Enter the sample standard deviation from your pilot sample in Cell J23.
12. If you've sampled from a finite population, the sample size is given in Cell J39. Round this number up to the next whole integer. For example, if Cell J39 shows 31.2, the sample size to use is 32. If you've sampled from an infinite population use the sample size given in Cell J37 and round up to the next whole interval. (Note: if Cells J13 and J14 were left blank, Cells J37 and J39 will give the same sample size.)
13. The worksheet gives you other information on your pilot sample, including confidence intervals for both the mean (Cells J27-J29) and total population (Cells J30-J32), and how well your sample performed in terms of Minimum Detectable Difference (Cell J43).

Example 1:

Our management objective is to maintain a population of more than 4,000 plants of Species X at Site Y over the next five years. Because this is framed in terms of a population total, we need to first convert the threshold to a mean number of plants/quadrat. We are sampling in a macroplot that is $10,000\text{m}^2$ and our quadrats are $0.5\text{m} \times 50\text{m} = 25\text{m}^2$. This means there are $N = 10,000\text{m}^2/25\text{m}^2 = 400$ possible quadrats in the population. Our threshold in terms of

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plants/quadrat is therefore 4,000 plants/400 quadrats = 10 plants/quadrat. Our sampling objective is be 90% certain of detecting a difference of 20% between our sample mean and the threshold, and we're willing to accept a 10% chance of making a false-difference error (concluding there is a difference when there really isn't one). Because we will fail to meet our management objective if the population is at or below 4,000 plants, we will use a one-tailed t test. If the sample mean is above the threshold *and* the test shows a significant difference between the mean of the sampled population and the threshold, we will conclude that our management objective has been met.

From our pilot sampling ($n=10$), we've calculated a mean of 8 plants/quadrat and a standard deviation of 4 plants/quadrat. Here is how we'd enter these data into the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

4. Enter 0.90 in Cell J6. This corresponds to our desired 90% power.
5. Enter 0.10 in Cell J7. This is the acceptable false-change error rate.
6. Enter 1 for 1-sided test in cell J8
7. Enter 2 in Cell J10. The 2 represents a 20% difference from the threshold of 10 plants/quadrat. This is the minimum detectable difference as specified in our sampling objective (we want to "detect a difference of 20% between our sample mean and the threshold").
8. Enter 10000 (the total population area) in Cell J13 and enter 25 (the area of a single quadrat) in Cell J14.
9. Enter 10 (the pilot sample size) in Cell J21.
10. Enter 8 (the sample mean) in Cell J22.
11. Enter 4 (the sample standard deviation) in Cell J23.
12. Read the sample size in Cell J39. Round this number (25.3) up to the next whole integer (26).
13. The worksheet gives you other information on your pilot sample, including confidence intervals for both the mean (Cells J27-J29) and total population (Cells J30-J32), and how well your sample performed in terms of MDC (Cell J43).

Example 2:

Here we use the situation described in the introduction to Procedure 6, above. Our management objective is to keep the canopy cover of the weed, medusahead, below 30% at Site Z over the next 5 years. Our sampling objective is be 90% certain of detecting a difference of 5% cover (as an absolute value) and we are willing to accept a 10% change that we will make a false-difference error. We are sampling inside a 5,000m² macroplot with 1m² quadrats.

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Because we will fail to meet our management objective if the estimated population cover is at or above 30% cover, we will use a one-tailed t test. If the sample mean is below the threshold *and* the test shows a significant difference between the mean of the sampled population and the threshold, we will conclude that our management objective has been met.

We estimate cover in quadrats, and from our pilot sampling ($n=15$) we've calculated a mean of 23% cover and a standard deviation of 11% cover. Here is how we'd enter these data into the Sound Science worksheet. Follow steps 1 through 3 as given above. We then enter the data from our example beginning with Step 4:

4. Enter 0.90 in Cell J6. This corresponds to our desired 90% power.
5. Enter 0.10 in Cell J7. This is the acceptable false-change error rate.
6. Enter 1 for 1-sided test in cell J8
7. Enter 5 in Cell J10. The 5 represents the 5% absolute difference we want to detect between the sample mean and threshold. Thus, if the sample mean is 25% cover we want a test comparing that value to the 30% cover threshold to be significant at $P < 0.10$. This is the minimum detectable difference as specified in our sampling objective (we want to detect a "difference of 5% cover (as an absolute value)."
8. Enter 5000 (the total population area) in Cell J13 and enter 1 (the area of a single quadrat) in Cell J14.
9. Enter 15 (the pilot sample size) in Cell J21.
10. Enter 23 (the sample mean) in Cell J22.
11. Enter 11 (the sample standard deviation) in Cell J23.
12. Read the sample size in Cell J39. Round this number (32.3) up to the next whole integer (33).
13. The worksheet gives you other information on your pilot sample, including confidence intervals for both the mean (Cells J27-J29) and total population (Cells J30-J32), and how well your sample performed in terms of MDC (Cell J43).