CALCULATION WORKSHEET: NUMBER OF PLOTS

2023 EDITION

phase
pollinator habitat aligned with solar energy

For general vegetation monitoring, you may select the number of plots based on the size of the area to be assessed. On many solar sites, selecting the number of plots may be based on limitations on time or resources, use of representative locations, or other factors. In these scenarios, more sampling can generally help users make informed decisions and that plots are spread out across your assessment area.

For users that want to answer more specific questions about the habitat being assessed, you should select the number of plots to assess based on your sampling objective(s). For example, you may want to compare two management approaches for effects on nectar plants or estimate the number of milkweed plants in your assessment area with a specific level of confidence. The number of plots you assess will impact your ability to answer your questions confidently.

See the Planning for Monitoring Guidance for help defining sampling objectives. This worksheet should be referenced during Step 6 *Calculate the number of plots required* of the Planning for Monitoring Guidance.

Guidance for Using the Calculation Workbook

The ROWHWG has developed a simple calculator (see *ROWHWG Habitat Assessment Plot Calculator.xlsx*) for estimating the number of plots required based on your sampling objective(s). Use the guidance below to complete the workbook. Please create a copy of the workbook to edit. You may want to duplicate the calculation sheet in the workbook if you have multiple strata.

For each sampling objective, calculate the number of plots required. Select the maximum number of plots calculated across all sampling objectives. If you have stratified the monitoring area, repeat this process for each stratum.

Objective Type

The number of plots required depends on whether the sampling objective is associated with a trend or threshold objective. For each sampling objective, input whether the objective is a threshold objective, trend objective using temporary plots, or trend objective using permanent plots.

Threshold objectives describe a target level for a vegetation attribute. The sampling objective is typically to ensure you are above, below, or between the target value(s) specified.

Trend objectives are used when you want to show progress towards a target. For trend objectives, the number of plots required depends on whether you are using temporary or permanent plots. Permanent plots are plots that are revisited in subsequent years. Permanent plots require fewer plots to identify a change over time, since you are comparing the exact same plot of vegetation.

Tip
Use permanent markers in the field, such as an array row end, marker post, pole, or other permanent, fixed feature as the starting corner of your plot to create permanent plots.

Standard Deviation

Standard deviation is a measure of the variability between plots for a specific vegetation attribute. The higher this variability is, the more plots needed to achieve a given level of confidence and power. You must estimate the standard deviation in the first year of monitoring if you don't already know it.

There are a number of strategies you can use to estimate standard deviation in the first year of monitoring:

1. **Use previous efforts**: others in the ROWHWG have collected data using the Pollinator Habitat Scorecard and can help you estimate standard deviation. The ROWHWG is working to provide estimates of standard deviation based on previously collected data. If you are aware of an organization that has already been using the Pollinator Habitat Scorecard in your region on similar vegetation types, you can also use those estimates.
2. **Use a pilot study**: a pilot study involves collecting a small number of plots in the first year to estimate standard deviation. A pilot study is also a good opportunity to test out other aspects of the Pollinator Habitat Scorecard and train your data collectors. See Equation 1 to calculate standard deviation from pilot data.
3. **Sequential sampling**: with this strategy, standard deviation is calculated after each additional point is collected until the uncertainty is reduced to meet the sampling objective. The challenge with this strategy is starting with a good estimate of the number of plots required--guess too low and you will run out of plots before getting the right level of precision; guess too high and you may end up collecting all of your data in one small area. A full discussion of sequential sampling is provided in Elzinga (1998)[1].

If you are using pilot data to estimate standard deviation, use the equations in the back to calculate the standard deviation or the standard deviation of the difference between paired plots (i.e., the same plot visited in two different periods).

Confidence Level

The confidence level describes how confident you can be that your data reflects the actual condition of your vegetation. Subtract the confidence level from 100% to get the false-change error rate, which is the probability of determining you met your target when in fact you did not. A confidence level of 80% is recommended for most objectives, however to meet the monitoring requirements of the CCAA you must use a confidence level of 90%. Higher confidence levels provide more certainty in your data but also require more plots.

Input the desired confidence level for each sampling objective.

Missed Change Error Rate

Describes the probability of not detecting a change that did in fact occur. The missed change error rate is only specified for trend objectives. Missing a change in vegetation can have profound impacts on management, especially if the missed change results in changing from one state to a worse state that will require significant management efforts to undo. A missed change error rate of 20% is recommended for the purposes of vegetation management.

Input the desired missed change error rate for each trend sampling objective; for threshold objectives leave blank.

[1] Elzinga, C.L., D.W. Salzer and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. Technical Reference 1730-1. Bureau of Land Management. Denver, Colorado. USDI, BLM

Minimum Detectable Change

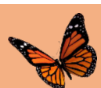
The minimum detectable change is the amount of change that you want to be able to detect. The smaller the detectable change, the more plots required. Consider the range of natural variability for a vegetation attribute, it's generally not worthwhile to detect a change smaller than what is biologically significant for that vegetation attribute. For trend objectives, consider selecting a minimum detectable change that is smaller than your management target to allow you to track progress towards the target over time.

Input the minimum detectable change for each sampling objective.

Tip
Consider adjusting the confidence level, missed change error rate, or minimum detectable change if the number of plots required is too high, or if you have resources available to collect more data.

After inputting all sampling objectives (for the first stratum, if applicable) the calculator will indicate the number of plots recommended to meet all sampling objectives. This is equal to the maximum number of plots required for each sampling objective.

You can now move on to step 7 *Distribute Plots* of the Planning for Monitoring guidance, or if the number of plots required exceeds what is feasible based on existing resources, review Strategies for Constraining Monitoring Costs.



CCAA Note
Confirm that the number of plots calculated meets or exceeds the requirements of the CCAA based on your adopted acres target (Table 14-4). Sampling objectives for the CCAA may differ from the sampling objectives of your organization. The CCAA requirements are intended to monitor the biological effectiveness of the agreement as a whole for monarch butterfly habitat. Meeting the minimum plots required based on adopted acreage will ensure that plots are spread out across the assessment area, when coupled with a randomized and spatially balanced plot distribution strategy.

Words of Caution

Oversample

An oversample is an excess number of plots collected to provide insurance against under-sampling. The more plots evaluated, the less likely it is that the confidence interval will be below the target, provided actual results are above the target. We recommend taking an oversample of 10% (i.e., generate 10% more plots than required) to allow for substitution of plots if a plot is unsafe or inaccessible and to allow additional data collection if variability is higher than estimated.

Low sample sizes

The sample size equation relies on a good estimate of the variance of the population, represented by the sample standard deviation. At very low sample sizes, using the sample standard deviation as an estimate of population variance is not very reliable. If the standard deviation changes significantly with additional samples, the sample size calculated will be off. If only very few samples are collected for any given area of interest, our confidence in those scores may be unreliable.

Additional samples may be required

The procedure presented here does not guarantee that the desired level of confidence and at the specified level of precision will be obtained if the number of samples calculated is taken. If additional variance is introduced, or if the parameter estimates change significantly, the number of samples required will change. Complete the sample size calculation iteratively, taking additional samples and recalculating each time, to reach the desired level of confidence and precision.

Take all additional samples before recalculating

Once you decide to take a set of additional samples, you must randomly locate those samples and collect data for each. If you stop halfway through, you may bias the results. An alternative is to collect data from the additional plots in a random order. That way you can stop sampling as soon as the sample adequacy equation results in zero additional samples are needed. However, if travel time between plots is a factor, this might not save time in the long run.

Normality

The equations proposed here assume that the population is distributed normally with respect to the parameter of interest. With large enough sample sizes (n>30), meeting this assumption is less important. However, at lower sample sizes, the level of confidence and precision we calculate will not be reliable if this assumption is not met.

Equations

This section describes the calculations used by the Calculation Workbook. These equations are provided for informational purposes only, you do not need to review this section to calculate the number of plots required.

Standard Deviation

Use the formula below to calculate standard deviation from sample (i.e., pilot) data.

$$s = \sqrt{\frac{\sum(X - \overline{X})^2}{n-1}}$$ ***Equation 1***

where:

s	sample standard deviation
X	value of observation *i*
X-bar	sample mean
n	number of samples

Standard deviation of the difference between two paired plots

When sampling units will be permanent, but only one year of data has been collected, the following equation can be used to estimate the standard deviation between paired samples using a correlation coefficient. The correlation coefficient can be estimated from existing studies in similar habitat. Herrick (2009)[2] recommends using a correlation coefficient of 0.5 based on results of a multi-year study in semi-arid environment if the correlation coefficient is unknown. (Note that in this case $s_{diff} = s_1$).

$$s_{diff} = (s_1) * \sqrt{2(1 - rho)}$$ ***Equation 2***

where:

S_{diff}	Estimated standard deviation of the difference between paired samples
s_1	Sample standard deviation among sampling units at the first time period
rho	Correlation coefficient between sampling unit values in the first time period and sampling unit values in the second time period

[2] Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett and W.G. Whitford. 2009. Monitoring manual for grassland, shrubland and savanna ecosystems. Volume II: Design, supplementary methods and interpretation. Tucson, Arizona: The University of Arizona Press.

Number of samples required for threshold objectives and trend objectives on temporary plots

The calculation of necessary sample size for each sampling objective based on the desired level of confidence and precision for the first assessment or when using temporary transects is shown below.

$$n = \frac{(s)^2 * (Z_\alpha + Z_\beta)^2}{(B)^2}$$ ***Equation 3***

where:

n	The sample size estimate
s	The population standard deviation
Z_α	The standard normal coefficient for the desired confidence level
Z_β	Z-coefficient for the desired statistical power
B	The desired precision level expressed as half of the maximum acceptable confidence interval width, specified in absolute terms.

Apply the Finite Population Correction Factor whenever you have sampled more than 5% of the population.

$$n' = \frac{n}{(1 + (n/N))}$$ ***Finite Population Correction Factor***

where:

n'	The FPC corrected sample size estimate
n	The uncorrected sample size estimate
N	The total number of possible samples in the population

Number of samples required for trend objectives on permanent plots

The calculation of necessary sample size when permanent transects are used based on the desired level of confidence and precision is shown below.

$$n = \frac{(s_{diff})^2 * (Z_\alpha + Z_\beta)^2}{MDC^2}$$ ***Equation 4***

where:

n	The sample size estimate
Z_α	The standard normal coefficient for the desired confidence level
Z_β	Z-coefficient for the missed-change error rate
s_{diff}:	The standard deviation of the differences between paired samples (when the samples are unpaired, 2 times the standard deviation of the previous sampling period should be used)
MDC:	The minimum detectable change size, expressed in absolute terms.

Table of Standard Normal Deviates

Use the values in the table below for Z_α and Z_β in the equations above. When in doubt, we recommend using the bolded levels in the table below (80% confidence level and 80% power).

Table of standard normal deviates (Z_α) for various confidence levels			Table of standard normal deviates (Z_β) for various statistical powers		
Confidence level	Alpha (α) level	Z_α	Power	Missed-change error rate (β)	Z_β
60%	0.4	0.84	60%	0.4	0.25
80%	**0.2**	**1.28**	**80%**	**0.2**	**0.84**
90%	0.1	1.64	90%	0.1	1.28
95%	0.05	1.96	95%	0.05	1.64
99%	0.01	2.58	99%	0.01	2.33

Note that when pilot study data is available, the Z-coefficients should be replaced with the appropriate t-values based on the degrees of freedom (df) associated with the sample size (n) (where df = n - 1).

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