

## How to Check for Significance by Adding Error Bars

When you conduct a scientific experiment, the mean of the random sample that you include in your experiment could still be different from the mean of the entire population. For instance, if you measured the height of seven randomly-chosen California sagebrush seedlings, the mean height for those seven seedlings is likely to be different than the mean height for the entire population of California sagebrush seedlings. If the results of an experiment are **statistically significant**, this means that you are very sure that the difference between two treatments is real. If the results are not statistically significant, it means that you can't be sure that your results aren't because of random chance.

A **confidence interval** shows you the range of numbers that the true mean for the entire population is likely to be between. You can use confidence intervals to determine if your results are likely to be statistically significant. In ecological research, scientists typically use a 95% confidence interval. This means that the range of numbers inside the confidence interval will include the true mean for 95% of experiments.

You can use **error bars** to show the confidence interval of a data set visually on a graph. (Error bars can also be used to show other ranges, like standard deviation.)

The function to calculate confidence intervals in google sheets is **=CONFIDENCE( alpha, STDEV, popsize)**. So to calculate the confidence interval (which you will use to create error bars on your graph), first you will need to determine the alpha, standard deviation, and population size.

### ***CALCULATING THE CONFIDENCE INTERVAL***

#### **Step 1: Set up your table.**

First, you'll want to set up the columns and rows in Google Sheets so that it is ready for you to enter data. Next to the cells where you calculated the average for each plot, label the next four columns so that they read Alpha, Standard Deviation, Population Size, and Confidence.

Your table should look like this:

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult	11.97142857				
No Adult	14.05714286				

**Step 2: Decide on the Alpha**

The alpha is the certainty of the interval. If you want a 95% confidence interval (which is standard for most ecological research projects), the alpha is 0.05.

Type in the alpha value in the column on your Google Sheet labeled “Alpha.”

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult	11.97142857	0.05			
No Adult	14.05714286	0.05			

**Step 3: Calculate the Standard Deviation**

You will also need to calculate the standard deviation for each of the two treatments. The standard deviation describes how your data is distributed (i.e., how much each data point is different from the mean.) To calculate the standard deviation, you can use the function **=STDEV()**. Type **=STDEV(**, then select all of the cells that you want to include. Finally, type **)** to close the formula.

Highlight the cells that include all of the data for one treatment.

Average Soil Moisture Reading		Average	Alpha	Standard Deviation
11.40	Adult Shrub	15.95		=STDEV(E4:E10)
22.45	No Adult Shrub	19.71	0.05	3.605996989
19.95				
13.00				
13.40				
17.35				
14.10				

This is what the formula will look like!

**Step 4: Determine the Population size**

This is the number of plots included in your sample. If you have soil moisture readings for seven different plots included in your sample, the population size is 7.

Make sure to enter this into your table as well!

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult	11.97142857	0.05	3.605996989	7	
No Adult	14.05714286	0.05	3.817332028	7	

**Step 5: Calculate the Confidence Interval**

Finally, you can calculate the confidence interval, using the formula **=CONFIDENCE(Alpha, STDEV, popsize)**.

For our Adult Shrub example below, the alpha is 0.05, the standard deviation is 4.073, and the population size is 7. This means the formula would be **=CONFIDENCE(0.05,4.073,7)**.

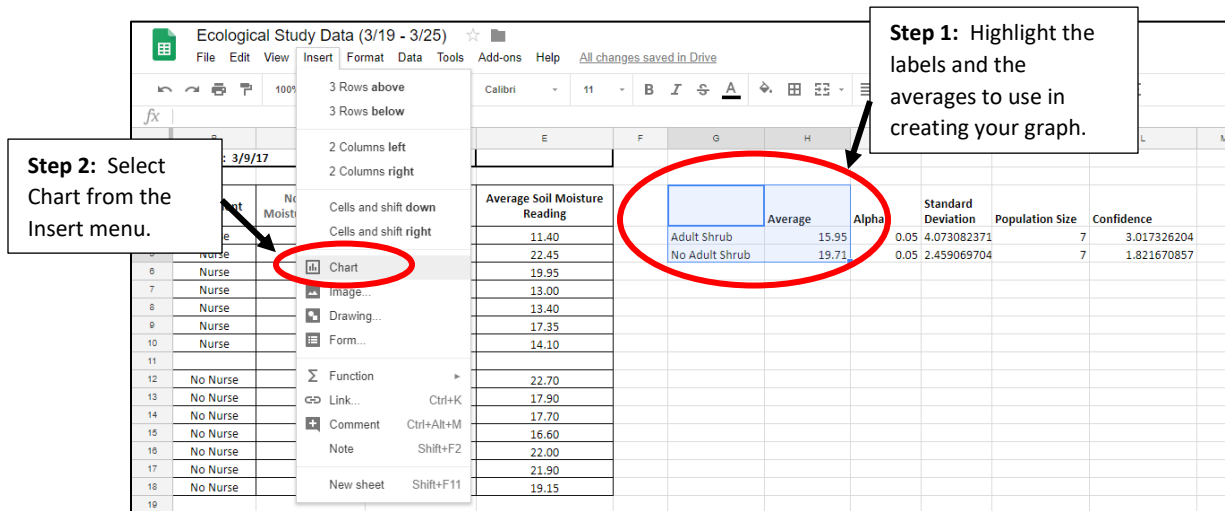
	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult Shrub	15.95	0.05	4.073082371	7	3.017326204
No Adult Shrub	19.71	0.05	2.459069704	7	1.821670857

Now that you have calculated the confidence interval for each of your treatment types, you can use it to add error bars to your graph! This will allow you to see if the confidence interval for the different samples overlap, or if there is likely to be a true difference between the two populations.

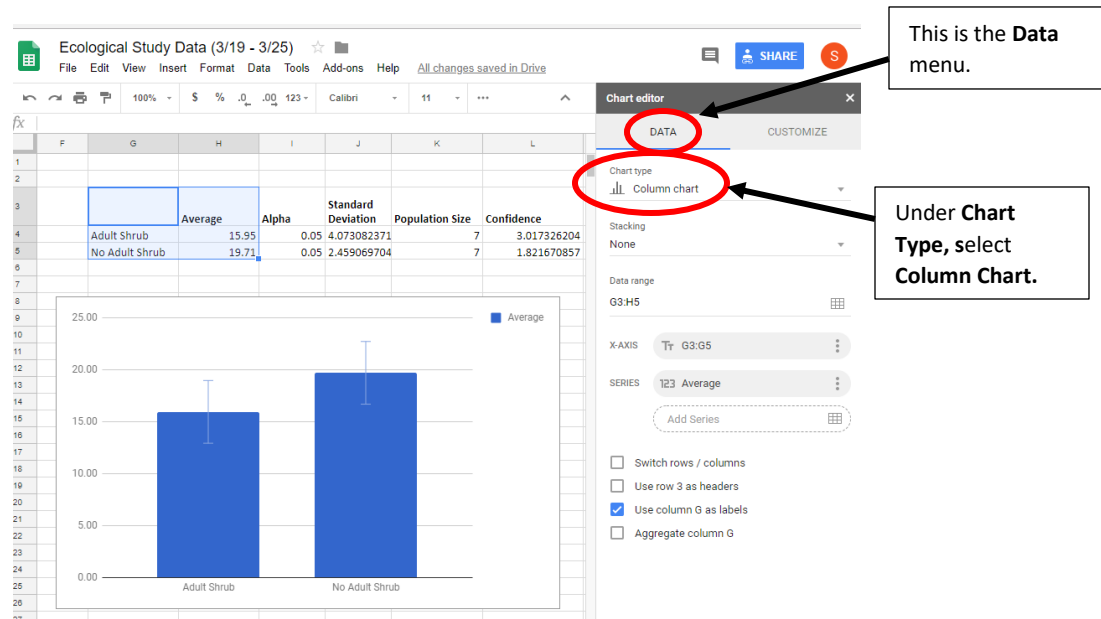
### ADDING ERROR BARS TO YOUR BAR GRAPH

Once you've calculated the confidence interval for each of the two treatments, then you will need to create a bar graph again! However, you will be doing a couple of things differently this time so that you can add error bars for each treatment.

1. First, highlight the cells with the averages.
2. Next, click on the **Insert** menu at the top of the browser, and then select **Chart** to create a graph.



3. Make sure that your graph is a bar graph. If it is the wrong type of graph, in the chart editor's **Data** menu, select the **Column Chart** option to change to a bar graph.



- Just like last time, you will probably have to adjust the scale on the vertical axis (or y-axis) of your bar graph. In the chart editor, click on **Customize** menu at the top, and then click on **Vertical Axis**. Make sure the minimum value for the axis is set at zero.

First, select the **Customize** menu.

Next, click on **Vertical Axis**.

Under the Vertical Axis menu, make sure the **Min** value is set to zero (0).

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult Shrub	15.95	0.05	4.073082371	7	3.017326204
No Adult Shrub	19.71	0.05	2.459069704	7	1.821670857

- In the chart editor, click on the **Data** menu again at the top. Select the option that says **Switch rows/columns**. This will make both of the data sets in the graph independent, so that the two bars show up in different colors: blue and red.

Click on the **Data** menu again to switch back over to the Data menu.

Select the box for **Switch rows / columns**. This will change your bar graph so that the two bars are different colors.

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult Shrub	15.95	0.05	4.073082371	7	3.017326204
No Adult Shrub	19.71	0.05	2.459069704	7	1.821670857

6. Next, switch back to the **Customize** menu, and select the **Series** sub-menu. (You can also double-click on the blue bar to open the Series sub-menu.)
7. Select the **Error Bar** option. This will add an error bar to the left bar in your graph. But you will still need to adjust it to make sure that the confidence interval is correct!

Ecological Study Data (3/19 - 3/25)

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult Shrub	15.95	0.05	4.073082371	7	3.017326204
No Adult Shrub	19.71	0.05	2.459069704	7	1.821670857

**Step 6:** Click on the **Customize** menu again, and then select the **Series** sub-menu.

**Step 7:** Click on the box to create an **Error bar** for your first treatment. (In this case, it is the Adult Shrub treatment.)

- You'll need to make sure that the graph is using the correct confidence interval for that particular data set. Under **Type**, select **Constant**. Under **Value**, enter the confidence interval for that data set. (In this case for our Adult Shrub treatment, the confidence interval that we calculated earlier was 3.017.)

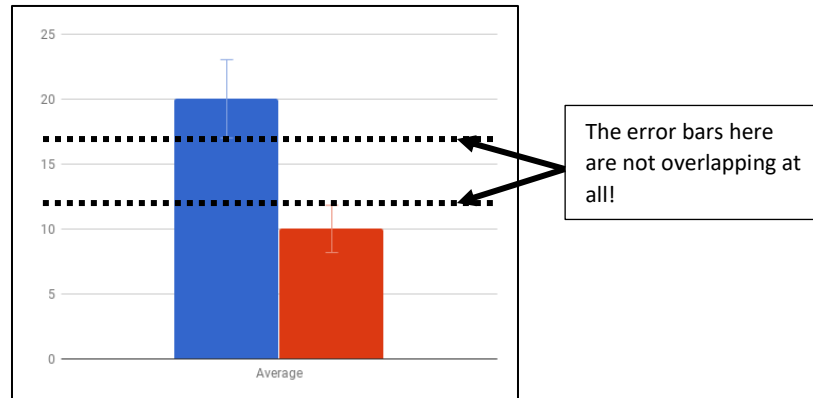
	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult Shrub	15.95	0.05	4.073082371	7	3.017326204
No Adult Shrub	19.71	0.05	2.459069704	7	1.821670857

- Finally, under **Apply to**, switch to **No Adult shrub**. Repeat steps 6-7 to add an error bar to the second bar. When you add the value this time, make sure to use the confidence interval for your No Adult Shrub data set. (In our example, this confidence interval is 1.82.)

	Average	Alpha	Standard Deviation	Population Size	Confidence
Adult Shrub	15.95	0.05	4.073082371	7	3.017326204
No Adult Shrub	19.71	0.05	2.459069704	7	1.821670857

**USING ERROR BARS TO DETERMINE IF YOUR FINDINGS ARE LIKELY TO BE SIGNIFICANT**

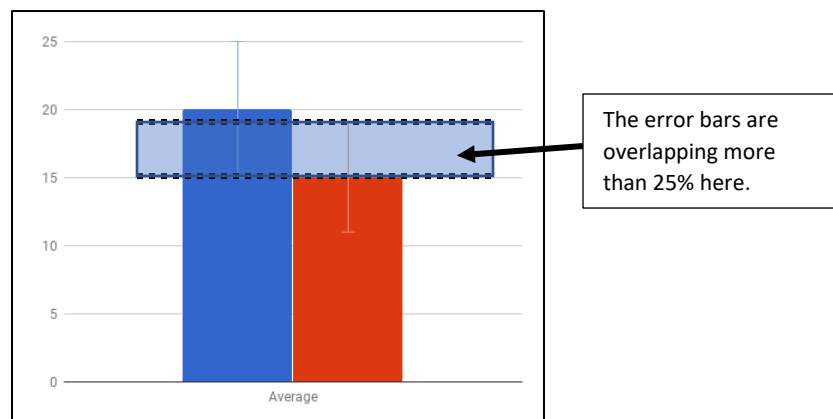
If your error bars **don't overlap at all**, then you can claim that your findings are likely to be highly significant, with a 95% confidence interval.



The error bars here are not overlapping at all!

If the error bars overlap **less than 25%**, then you can claim that your findings are likely to be significant, with a 95% confidence interval.

If the error bars overlap **more than 25%**, then you would say that your findings do not appear to be significant. This might be because there is no real difference between the populations. It could also be because your sample size is very small. Since you are only analyzing the data from seven plots in each treatment, it may be difficult to get significant results.



The error bars are overlapping more than 25% here.

If you encounter an overlap, you are welcome to contact Crystal Cove Conservancy, and we can send you the full data set with all 70 plots to analyze. Including more replicates and more data points may make it more likely that you will get significant results.

If the error bars look close and you can't tell if they overlap less than 25% or not, please feel free to reach out to us as well! There are other more complicated statistical analyses that we can run to determine if your results are statistically significant or not.