2. Creating Bar Graphs with Excel 2007

Biologists frequently use bar graphs to summarize and present the results of their research. This tutorial will show you how to generate these kinds of graphs (with error bars) using a biologically relevant student-generated data set.

As part of her senior thesis research on territoriality in the Mountain Dusky Salamander (*Desmognathus ochrophaeus*), Samantha Witchell (Class of 1999) investigated the role of prior occupancy on the outcome of territorial interactions and aggressive behavior. Samantha staged encounters between a male that had been allowed to establish a territory in a laboratory arena ("resident") and a comparably sized male without any prior residency ("intruder"). In order to control for the effects of body size, males were categorized into three size classes; small one-year-old males (30-33 mm snout-vent length), medium-sized two-year-old males (36-39 mm), and large adult males (42-45 mm). The resident and intruder used in a particular trial were matched by size, and Samantha staged a total of eight encounters for each of the three size classes. In each trial, Samantha allowed the two salamanders to interact with each other for 20 minutes, during which time she collected data on several different behaviors. One of the behaviors she recorded was the "all trunk raised" (ATR) posture, an aggressive posture used by males in territorial encounters. Here are data she collected on the number of ATR postures performed by residents and intruders.

	30-33 mm		**36-39 mm**		**42-45 mm**	
Trial	*Resident*	*Intruder*	*Resident*	*Intruder*	*Resident*	*Intruder*
1	1	0	3	0	4	1
2	2	0	2	0	2	0
3	0	0	2	1	2	0
4	1	0	1	0	1	0
5	0	1	2	1	3	1
6	0	0	1	0	1	2
7	0	0	0	0	2	0
8	0	0	3	0	2	0

How can these data be summarized in an effective graph?

<u>I. Use Excel 2007 to Calculate Summary Statistics</u>

1. Click on the "Microsoft Office button on the top left corner to perform file operations such as "New", "Open, "Save As", "Print", etc. Open a new workbook in Excel and enter the data on Sheet1 in the format shown at right: When the data are entered (Figure 2.1), save the worksheet and name it "BarGraphExample".

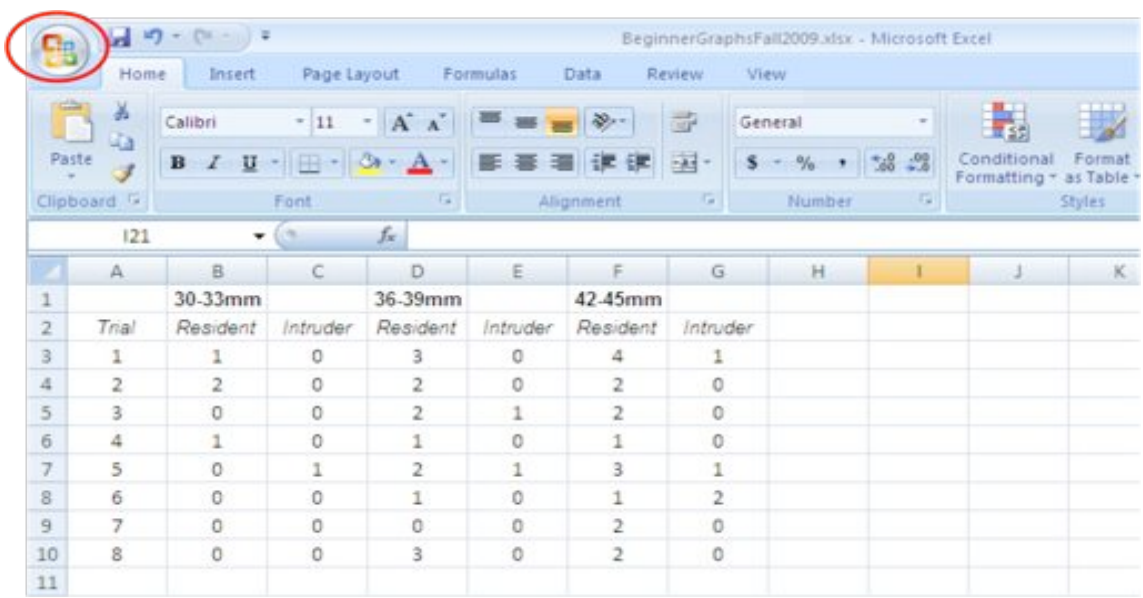


Figure 2.1

2. Once you have entered the data, you can use Excel to calculate the summary statistics to be plotted on your graph. In cell **B12** type:

=AVERAGE(B3:B10)

When you hit the return key, Excel will automatically calculate the *mean* (average) number of ATR postures by small residents, using the 8 values entered in cells B3 to B10.

3. You can also use Excel to calculate the *standard error,* a measure of the reliability of the calculated mean. The standard error is calculated by dividing the standard deviation (explained below) by the square root of the sample size. Persuading Excel to do these calculations requires a few additional steps:

A. In cell **B13**, type:
=STDEV(B3:B10)

When you hit the return key, Excel will automatically calculate the *standard deviation* of the number of ATR postures by small residents, again using the 8 values entered in cells B3 to B10. The standard deviation is a measure of the amount of variation in the data set; if all the observations are close to the mean value, the standard deviation is small. If most of the observations differ greatly from the mean, then the standard deviation is large.

B. In cell **B14**, type

=SQRT(COUNT(B3:B10))

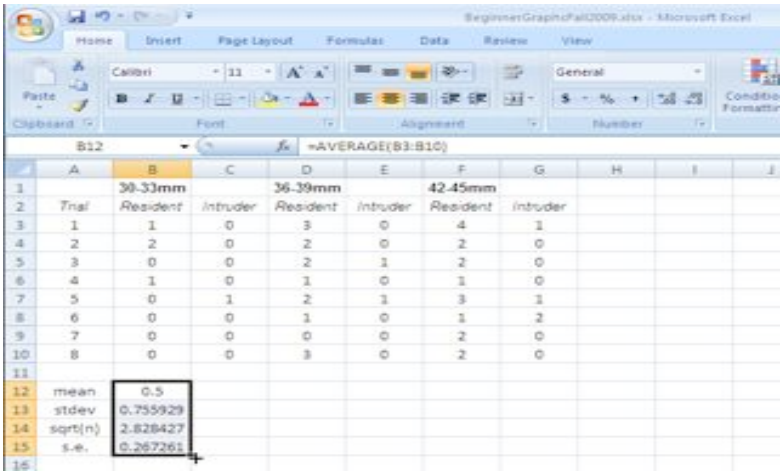
When you hit the return key, Excel will automatically count the number of observations (8 in this particular example) and determine the square root of this number (2.828).

C. In cell **B15**, type

=B13/B14

When you hit the return key, Excel will automatically divide the value in cell B13 (the standard deviation) by the value in cell B14 (the square root of sample size), thereby giving you the standard error.

You could repeat the above steps to write formulas for the data in the other columns. However, it is much easier to let Excel copy the formulas to the other columns. To do this, use the mouse to select the area from cell **B12** to cell **G15**, so that the worksheet now looks like Figure 2.2.



Move the pointer over the little black square on the lower right of the selection; the pointer will change from a large white cross to a smaller black cross. Now left-click and drag over to column **G** to copy and paste the formulas for column **B**. Another method is to use the keyboard shortcut **CTRL-C** to copy the selection and then use the mouse to select the cells C12:G15 and then type **CTRL-V** to paste.

II. Using Excel to Create Graphs

Now that Excel has crunched the numbers for you, it's time to plot them in a bar graph.

1. First, click on cell **B1** (the cell containing the label for the smallest size class). Then, **while holding down the CTRL key**, click on the other two cells containing the labels for the size classes (**D1** and **F1**) and the three cells containing the mean values for the Resident (**B12**, **D12**, and **F12**).

2. Under the **"Insert"** menu, choose **"Column"** in the **"Chart"** section in the Ribbon along the top, and choose **"Clustered Column"** on the top left of the chart choices (Figure 2.3).

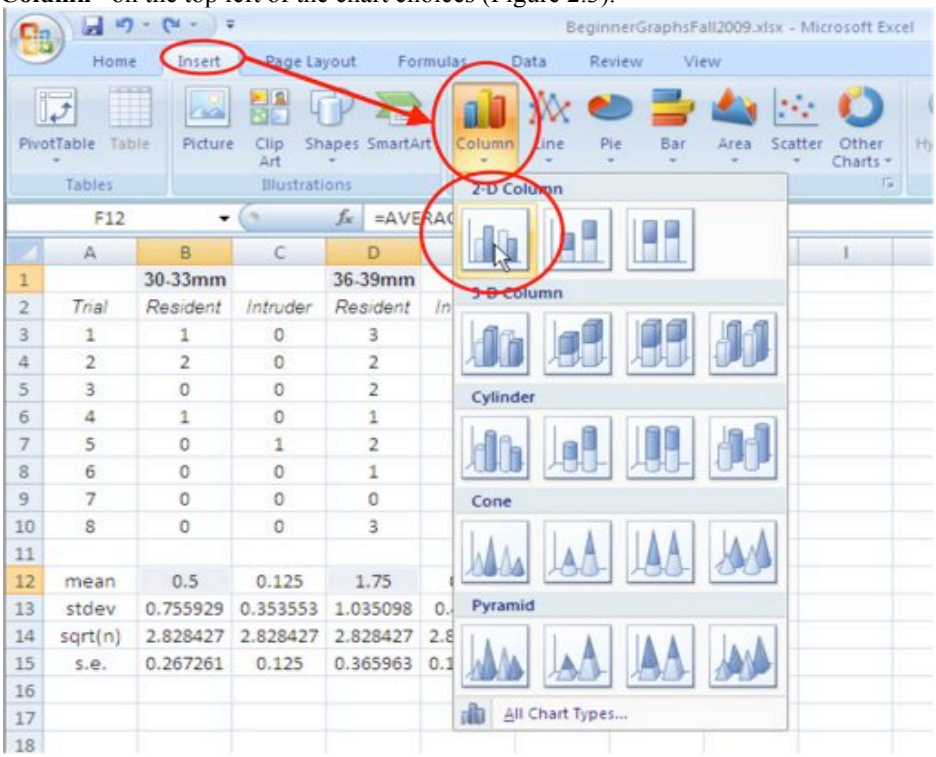


Figure 2.3

3. The chart produced in the previous step is incomplete. Click somewhere in the white space in the far right of the chart to select it. You should now see **"Chart Tools"** along top bar, with the choices **"Design"**, **"Layout"**, and **"Format"** underneath it (Figure 2.4). After selecting the chart, **drag it over to the right so that it does not block your data!**

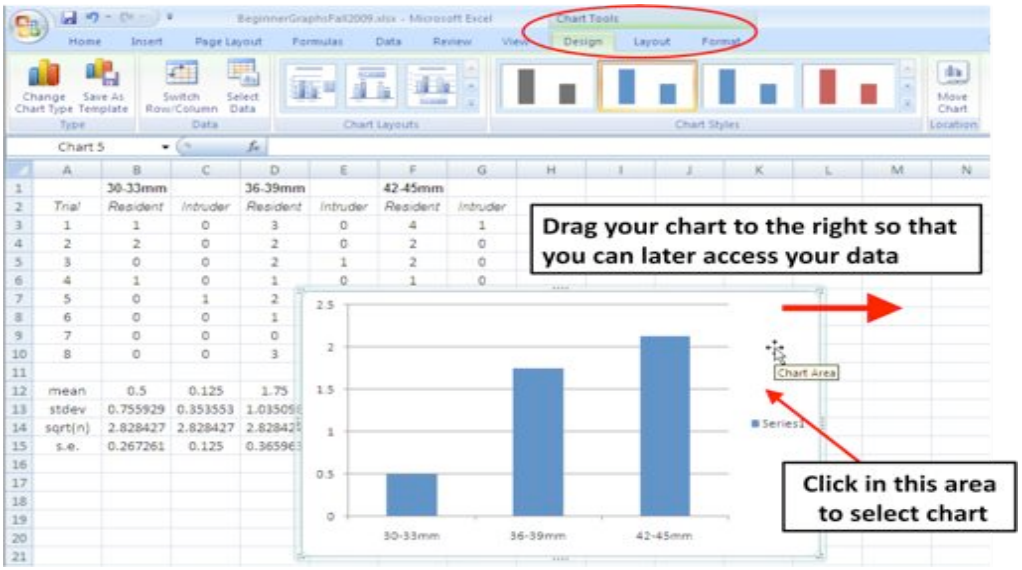
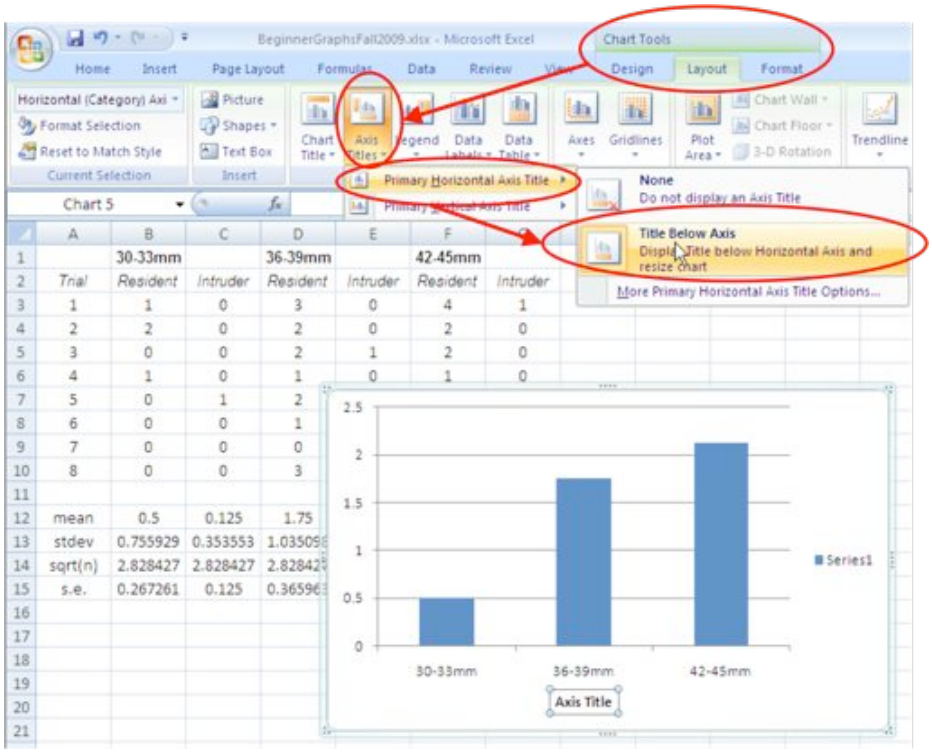


Figure 2.4

Choose **"Layout"** and then **"Axis Title"** (in the **"Labels"** subgroup that appears) , then **"Primary Horizontal Axis"** and finally **"Title Below Axis"** (Figure 2.5). Now you can click in the "Axis Title" box that appears below the horizontal axis and type in an appropriate title (describe the variable and give its units if necessary). You can similarly add an axis title for the vertical axis.



You may decide that the graph looks better without gridlines – you can turn them off by left-clicking to select them, and then right-clicking and choosing **"Delete"** from the pop-up menu. An alternate method is to select the entire plot and choose **"Chart Tools" > "Layout" > "Gridlines" > "None"** from the top menu.

4. Now we can add the data for "Intruders" to the graph.
Select the chart (Figure 2.3), and then choose **"Design" > "Select Data"** and then **"Add"** in the dialog box that appears (Figure 2.6). You can give the new series the name "Intruders" and select the cells **C12**, **E12**, and **G12** (hold down the **CTRL** key). Notice that the first series still doesn't have a name – select that series and then choose "Edit" to change the name. Click "OK" in the dialog box to accept your changes.

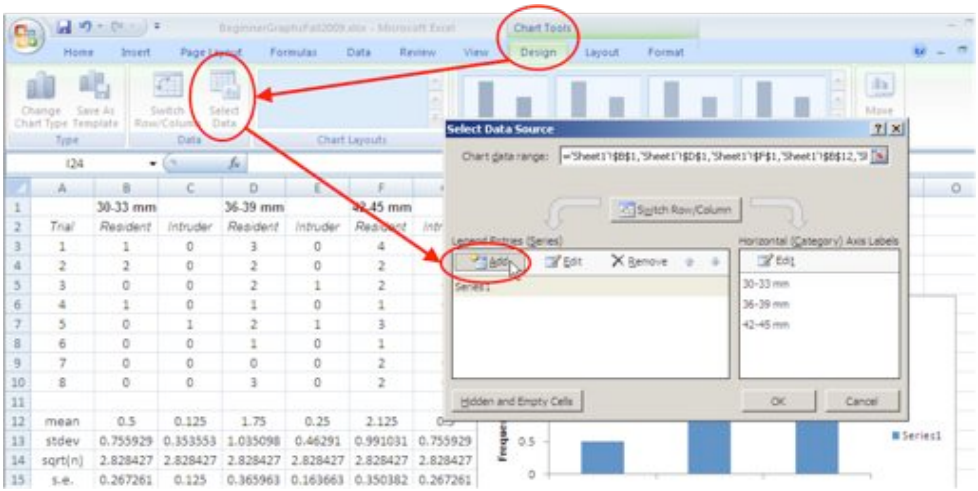


Figure 2.6

III. Adding Error Bars

1. Click once on one of the three bars corresponding to the "Residents" to select that data series – be sure to check that all three bars of the "Resident" series are selected.

2. Choose **"Chart Tools" > "Layout" > "Error Bars" > "More Error Bar Options"** (Figure 2.7). **Do <u>NOT</u> choose the given "Standard Deviation" or "Standard Error" options – these lead to incorrect error bars!**

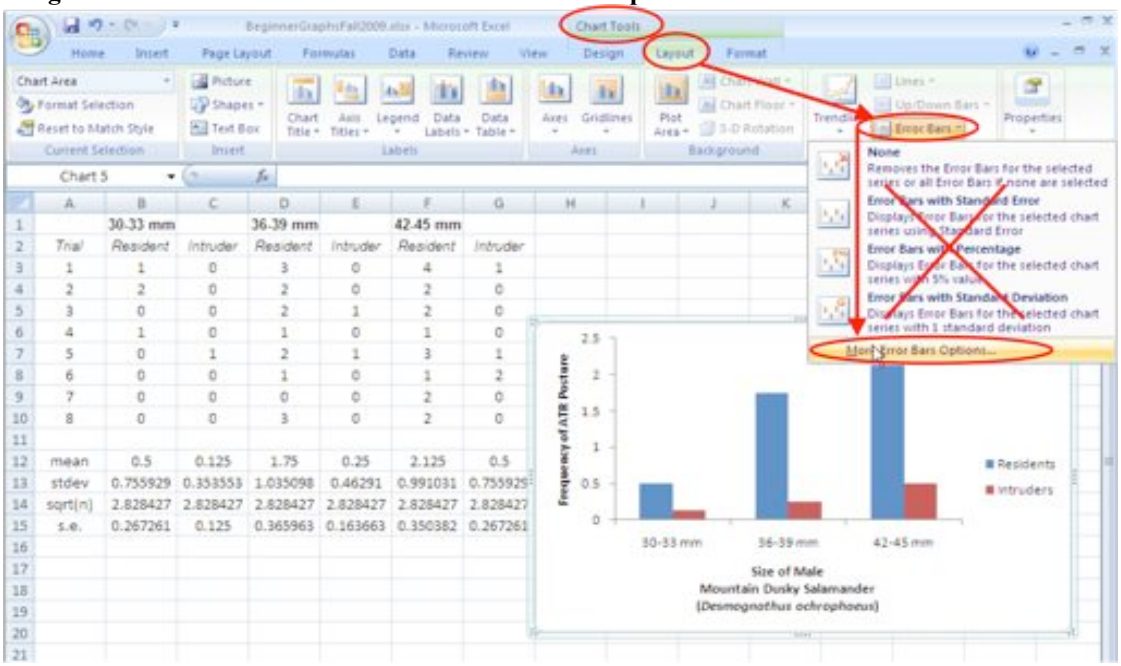


Figure 2.7

3. IMPORTANT: you may need to uncover some of data that is being blocked by the "Format Error Bars" popup window (Figure 2.8).

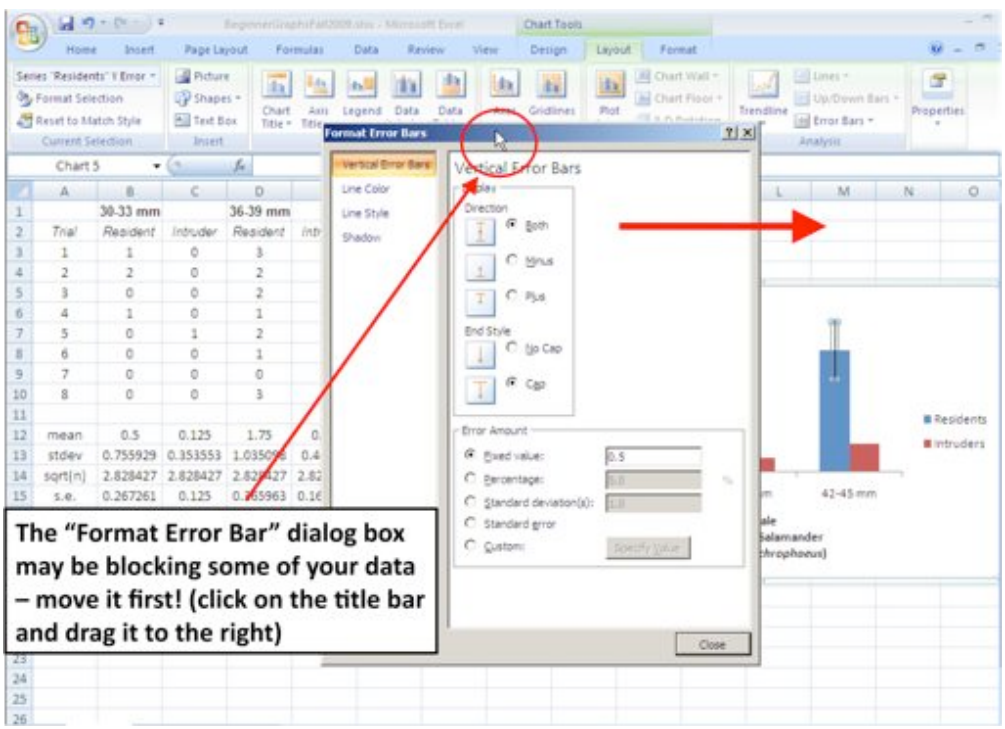


Figure 2.8

4. Click on the "Custom" toggle button at the bottom of the list of choices, then click on "Specify Values". **Be sure to delete the default entries in the "Custom Error Bars" popup window before selecting your data!** (Figure 2.9) For the "Resident" data series error bars, you will want to select cells **B15**, **D15**, and **F15** (hold down the **CTRL** key while selecting). Click on the Close button when you have completed the task.

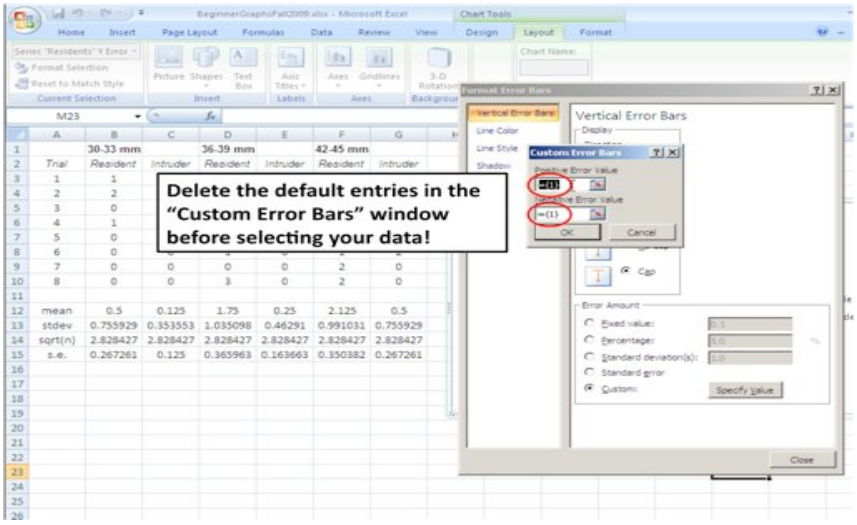


Figure 2.9

5. Repeat steps 1-4 for the "Intruder" data series, selecting cells **C15**, **E15**, and **G15**.
   Hint: if your error bars all appear to be the exact same size, it is possible that you have incorrectly added your error bars!

<u>IV. Fine-Tuning Your Graph</u>

With Excel, you have control over virtually all aspects of chart appearance. Experiment by left-clicking on the various chart components (legend, x-axis, y-axis, data series, y-error bars, etc.), and then right-clicking to bring up a popup menu of choices for changing fonts and font sizes, fill and background colors, etc. You can also experiment with re-sizing and re-proportioning your graph by clicking once on the plot frame and dragging the square "handles" around the edges. Experiment and make changes until you are happy with your graph. But don't go too wild! The best graphs are clean, simple, easy to interpret, and effective. You can also move your chart to its own worksheet by choosing **"Chart Tools > "Design"** and then **"Move Chart Location"** (far right of the "Design" ribbon that appears). When you are happy with your final graph, save your workbook! You can then select, copy, and paste the chart into Word or other word processing applications. One possibility for a final, finished graph, with an appropriate and concise figure legend appears in Figure 2.10 below

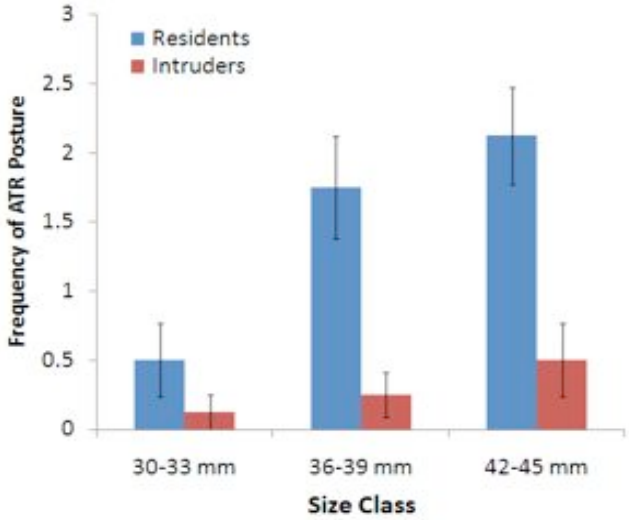


Figure 2.10. Mean number of ATR (all trunk raised) postures per 20-minute trial for resident and intruder Mountain Dusky Salamander (*Desmognathus ochrophaeus*) in the three separate size classes (*n*=8 each class). Error bars represent the standard error of the mean.