

## Community Ecology

### Objectives

- Produce and analyze graphs of temperature change using large, long-term data sets
- Evaluate data “cherry-picking” as a means to lead to misinformation
- Interpret statistical models (e.g. regression analysis) and apply these to ecological phenomena
- Describe the ecological consequences of flowering shifts and animal phenology
- Understand how interaction between species and their abiotic environment affect community structure and species diversity

### Lab Activities

**(Hand-in pp. 3-9 at the end of lab today.)**

#### I. BACKGROUND

Climate change as a result of anthropogenic greenhouse gas (GHG) emissions is clear in both climatological and biological data. Global temperatures have increased by  $0.74^{\circ}\text{C} \pm 0.18^{\circ}\text{C}$  over the past 100 years (1906-2005), although some regions experience locally greater warming (IPCC 2007). Along with this average increase in temperature, extreme weather events including extreme heat have become more common. The ten hottest years on record have all occurred since 1998.

Scientists use long-term climate (for example, see Figure 1) and biological datasets to assess past and current rates of warming and the impacts of this warming on key ecosystem functions. These analyses provide crucial information for the prediction of future impacts of warming as we continue to release massive quantities of GHGs into the atmosphere.

One clear biological indicator of climate change is phenology, or the timing of key life events in plants and animals. Phenological events are diverse and include time of flowering, mating, hibernation, and migration among many others. Generally, phenological events are strongly driven by temperature, with warmer temperatures typically resulting in earlier occurrence of springtime migration, insect emergence from dormancy, and reproductive events. Shifts in phenology in the direction

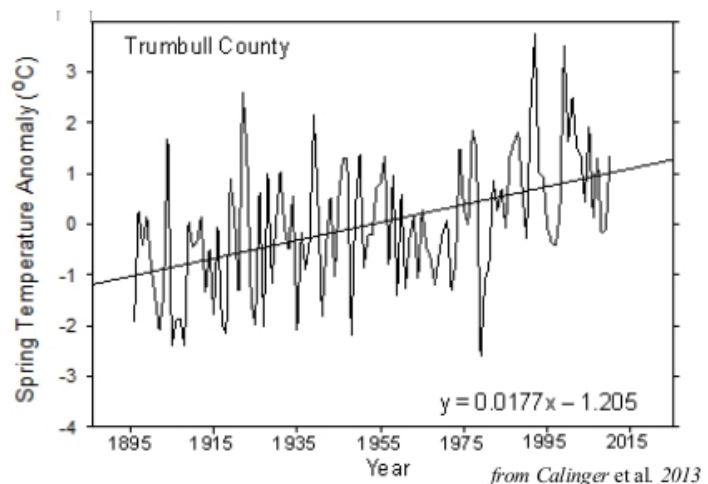


Figure 1. Spring temperature trends in Trumbull County, OH using yearly spring (February through May) temperature anomalies from 1895-2009. A simple linear regression line was used to determine shifts in spring temperatures over the 115-year period. This regression line (see equation in graph) indicates that Trumbull Co. has experienced a  $2.0^{\circ}\text{C}$  average spring temperature increase.

predicted by climate change have been observed worldwide, suggesting that climate change is already having profound, geographically broad impacts on ecology (Parmesan & Yohe 2003, Menzel et al. 2006; Rosenzweig et al. 2008).

In this lab, you will be analyzing long-term temperature data collected in Ohio by the U.S. Historical Climatology Network (<http://cdiac.ornl.gov/epubs/ndp/ushcn/ushcn.html>) to establish temperature trends in Ohio over the past 115 years. You will then investigate temperature effects on the flowering of six plant species and the arrival and emergence times of two pollinator species to determine biological signals of climate change in Ohio.

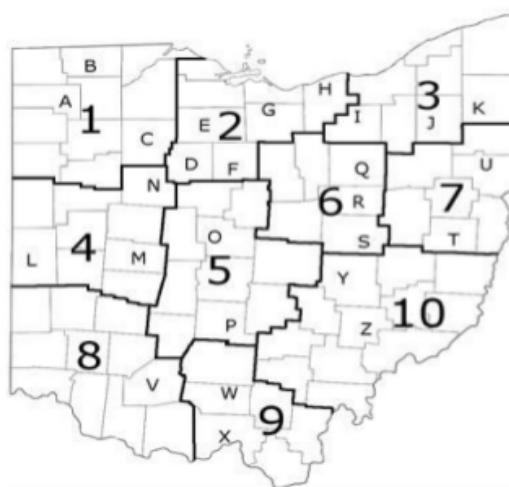


Figure 2. The ten NOAA climate divisions in Ohio and the location of the 26 USHCN weather stations (labeled A-Z).

## II. PROCEDURES

### **A) Regional Long-term Temperature Trends**

The data for these exercises should be downloaded at this link [Phenology Data](#). You will work in pairs and/or table groups to analyze the data.

An important component of climate change studies is the analysis of temperature change over long timescales in the region of interest. For our analysis of Ohio, you will assess temperature change across the entire state as well as at smaller, regional scales. The U.S. Historical Climatology Network (USHCN) has collected temperature and precipitation data at 26 weather stations throughout Ohio since 1895 (Figure 2). The number of USHCN weather stations is limited as USHCN stations are required to have a consistent, non-urban location since 1895; this eliminates urban heat island effects (urbanized areas that are hotter than surrounding rural areas, U.S. EPA) and latitudinal/altitudinal effects. Changes in the location of weather stations can cause apparent increases or decreases in temperature as a result of moving to a generally warmer or cooler location. These possible altitudinal or latitudinal effects are eliminated in the USHCN climate record by requiring consistent station locations since the start of data collection. Using the mean of temperatures recorded at all 26 weather stations in Ohio, we can evaluate statewide trends in temperature since 1895.

To assess regional trends in temperature, we can use the ten climate divisions in Ohio established by the National Oceanic and Atmospheric Administration (NOAA, see Figure 1).

Look at the [Excel file](#) with the phenological and climate data. The temperature record for each climate division is given in separate worksheets. Each climate division worksheet includes two columns; “Year” provides the year in which the temperature data were collected, and “Temp (deg C)” provides the spring time temperature for that year in degrees Celsius. These division temperatures were calculated by averaging the temperature records for every USHCN weather station in that division for the year of interest from February to May (spring temperatures). For example, Division 1 temperatures are the mean Feb.-May temperatures of USHCN weather stations A, B, and C (Figure 2).

With your partner, pick two climate divisions you will analyze.

1. Looking at the data for the two climate divisions you have chosen to analyze, how would you determine temperature change from 1895-2009? In your answer, address the following questions: What are your independent and dependent variables? What type of graph would be useful and why? What statistics would you use to extract the rate of temperature change from that graph? How would you calculate total temperature change over the 115 year period?

2. Based on your answer to the question above, produce a plot of temperature change for each of your climate divisions of interest (two graphs total). Using these graphs, record the rate of change ( $^{\circ}\text{C}/\text{year}$ ) and total temperature change ( $^{\circ}\text{C}$ ) from 1895-2009 in the table below and on the chalk board for the whole class.

Division	Rate of Temperature Change ( $^{\circ}\text{C}/\text{year}$ )	Total Temperature Change ( $^{\circ}\text{C}$ )

3. Is temperature increasing, decreasing, or remaining stable in your climate divisions? Do your divisions show similar trends or are they different?

Another tool commonly used by climate change scientists is a temperature anomaly plot. Yearly temperature anomalies indicate how much warmer or colder a given year is compared with the long-term average temperature. These plots are useful because they clearly indicate anomalously warm and cold years while still providing information on long-term temperature trends.

To calculate yearly temperature anomalies for your division, you first need to calculate the average spring-time temperature ( $^{\circ}\text{C}$ ) for your division. Simply calculate the mean of all 115 temperatures in your division. Next, subtract the mean temperature from each of the yearly temperature values to produce yearly temperature anomaly values.

4. If the temperature anomaly for a given year is negative, what does this mean?

5. If the temperature anomaly for a given year is positive, what does this mean?

6. What type of graph should you use to analyze temperature anomaly data?

7. Based on your answer to question 6, produce a temperature anomaly graph for each of your climate divisions of interest (two graphs total). Using these graphs, answer the following questions:

Division	Rate of Temperature Change ( $^{\circ}\text{C}/\text{year}$ )	Total Temperature Change ( $^{\circ}\text{C}$ )

8. Are the temperature change rates and total temperature change values the same as in your original graphs? Why?

**B) Statewide Long-term Temperature Trends**

Click on the worksheet labeled "[State T Trends](#)." The temperature and temperature anomaly data have been provided for you. Plot these data to calculate the statewide rate of temperature change and total temperature change over the past 115 years.

1. What is the statewide rate of temperature change ( $^{\circ}\text{C}/\text{year}$ )? \_\_\_\_\_

2. How much has spring time temperature ( $^{\circ}\text{C}$ ) in Ohio changed over the past 115 years?

\_\_\_\_\_

3. Your instructor will show you spring temperature change values for each of the 10 divisions, if they have not yet been written on the board. Is temperature change even across the state or do some divisions show greater change than others? Use specific examples of division temperature trends in your answer.

4. Why is it important to assess temperature change across large areas rather than simply at small, regional scales (such as climate divisions)? How might climate change skeptics use long-term temperature data collected in small regions to present misleading temperature trends? Provide specific divisions as examples of this tactic in your answer.

### C) Biological Indicators of Climate Change: Flowering Time

Flowering time is a crucial phenological event for plants as it can strongly impact reproductive success (Calinger *et al.* 2013). Previous research has shown significant advancement of flowering with temperature increase (called phenological responsiveness, days flowering shifted/°C), although species vary in the degree to which they shift flowering with temperature change. Since flowering time can have substantial fitness effects, climate change may alter species performance as climate warms, causing some species to decrease in abundance. You will analyze data on Ohio flowering times and assess impacts of temperature increase on species diversity.

Click on the worksheet labeled “[Flowering data](#).” This worksheet provides data on the dates of flowering for six plant species collected throughout Ohio as well as temperature data and additional descriptive data ([Calinger \*et al.\* 2013](#)).

Look at the column headings: Species, Common Name, County, Year, Division, Temperature, and DOY. Species and Common Name specify the plant species of interest. Each row represents an individual observation for a given species. County and Division provide information on the county of observation and the NOAA Climate Division in which that county is found. Year simply indicates the year in which the observation was made.

Flowering dates are given in the “DOY” column. DOY stands for “day of year” and is the numeric day of year (day 1=Jan. 1, Dec. 31=365, and so on) that the plant was flowering. Each flowering date is paired with a temperature specific to the individual plant’s location, year, and season of observation. This temperature (°C) is given in the Temperature column.

1. Given these data, how will you assess phenological responsiveness (days/°C) for each species? Consider the following questions in your answer: What are your independent and dependent variables? What type of graph would be appropriate for your data? What statistical technique will you use to determine your phenological responsiveness value for each species?

2. Based on your answer above, create a graph showing the relationship between flowering date (DOY) and temperature for each of the six species. Use these graphs and the appropriate statistics to determine phenological responsiveness values for each species and fill in the chart below.

<b>Species</b>	<b>Flowering Shift (days/°C)</b>
<i>Carduus nutans</i>	
<i>Castilleja coccinea</i>	
<i>Cornus florida</i>	
<i>Clematis virginiana</i>	
<i>Aquilegia canadensis</i>	
<i>Cypripedium acaule</i>	
<b>Average Flowering Shift</b>	

3. Do all species exhibit identical shifts in flowering time with an increase in temperature, or do some species advance/delay flowering more than others as temperature increases? Use specific species as examples in your answer.

4. Based on the average shift in flowering (days/°C) over all species, is flowering time in Ohio changing with warming temperatures? On average, how much would flowering shift with a 1°C or 2°C temperature increase?

5. Based on your flowering shift calculations for each species, will all species be equally well adapted to our warming Ohio climate? What impacts might this have on Ohio species diversity (we will consider species richness, or the total number of species in a given area, as our measure of species diversity)? Explain.

## D) Biological Indicators of Climate Change: Butterfly Emergence and Hummingbird Arrival Times

Along with shifts in the timing of plant phenological events, scientists have observed significant shifts in the timing of animal phenological events such as migration, insect emergence, and mating associated with temperature increase (Cotton 2003). Like flowering time in plants, the timing of these phenological events has direct impacts on reproductive success in animals.

Further, changes in the timing of phenological events in plants and animals may disrupt important plant-animal interactions such as pollination. These disruptions of interactions as a result of shifting phenology are called trophic mismatches. For example, in pollination mutualisms, the pollinator benefits from pollen and nectar food resources and the plant benefits by being pollinated and increasing its reproductive success. Under average climate conditions, without climate change associated warming, flowering time in the plant and arrival time of the pollinator (based on migration or insect emergence date) are cued to coincide. However, if the plant or pollinator responds more strongly to climate warming and shifts their phenology more than their mutualistic partner, this relationship will be disrupted. This trophic mismatch results in decreased pollination and reproduction for the plant and a loss of important floral food resources for the pollinator.

Using data provided below, you will be assessing the effects of warming on shifts in arrival time of the migratory ruby throated hummingbird, *Archilochus colubris* and emergence from overwintering of the Spring Azure butterfly, *Celastrina ladon* (data from Ledneva *et al.* 2004). Both of these species occur in Ohio although this data was collected in Massachusetts. For this study, we will assume that the responses of both the ruby throated hummingbird and the Spring Azure butterfly are uniform throughout their ranges. You will also discuss whether we have evidence for trophic mismatches based on your findings.

Species	Arrival Time Change (days/°C)
<i>Celastrina ladon</i> (adults)	0.55
<i>Archilochus colubris</i>	-1.40

1. Based on the data given above for arrival time change, describe the pattern of shifting arrival/emergence time phenology for each pollinator species.

2. *Archilochus colubris* uses *Aquilegia canadensis* (columbine) flowers as a nectar food resource, and, in turn, is an important pollinator of this plant (Bertin 1982). *Celastrina ladon* caterpillars feed on *Cornus florida* (flowering dogwood) flowers (University of



Florida IFAS Extension), although this interaction is not mutualistic as the dogwood receives no benefit. Given your knowledge of flowering shifts with temperature in *A. canadensis* and *C. florida* as well as arrival time shifts with temperature in *A. colubris* and *C. ladon*, speculate on what effects climate warming might have on survival and reproduction in these species. How would species interactions change with a 1°C temperature increase? With a 3°C temperature increase?

### E) Debunking a Climate Change Skeptic Tactic

Climate change skeptics often try to argue that temperatures have not been increasing and present misleading data to support their point. Frequently, they use a tactic called “cherry picking” data. Cherry-picking data involves including only the data that supports whatever point you are trying to make while disregarding the rest of the data that would discredit that point.

Look at your plot of spring temperature change across Ohio. The data indicate a significant temperature increase of about 0.9°C since 1895. In fact, 3 of the 5 warmest years in the temperature record are in the 1990's and 2000's.

Now plot statewide temperature including ONLY yearly spring temperatures from 1990-2009.

20. Does your plot indicate temperature increase or decrease from 1990-2009? What is the rate of temperature change?

21. Based on the long-term, 115-year assessment of temperature change versus the shorter, 20-year assessment, can we accurately assess temperature change using a small subset of the data? Refer to the data in your answer.

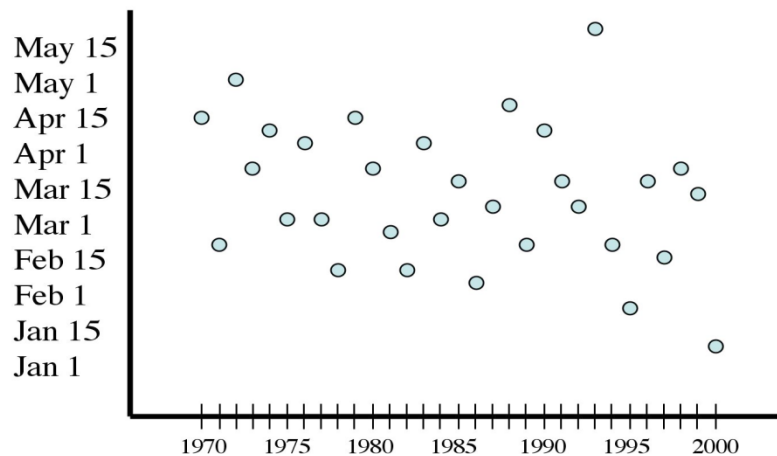
22. Why is it inappropriate to use only a subset of the total years to establish a climatic pattern?

## F) Excel Help

There are three main skills that you need to complete the activities. The first two involve making graphs of data, and the last one involves a statistical analysis. The last topic is advanced, and may include information that you have not encountered in your math classes.

### a) How to make a graph

The goal is to make a simple scatterplot of data, like this (note: these examples are using butterfly phenology and climate data):



	A	B	C	D
1	YEARS	A_campestris		
2	1972	109		
3	1973	125		
4	1974	106		
5	1975	129		
6	1976	90		
7	1977	103		
8	1978	118		
9	1979	110		
10	1980	106		
11	1981	101		
12	1982	114		
13	1983	142		
14	1984	106		
15	1985	80		
16	1986	80		
17	1987	94		
18	1988	76		
19	1989	96		
20	1990	96		
21	1991	102		
22	1992	96		
23	1993	96		
24	1994	90		
25	1995	106		
26	1996	89		
27	1997	100		

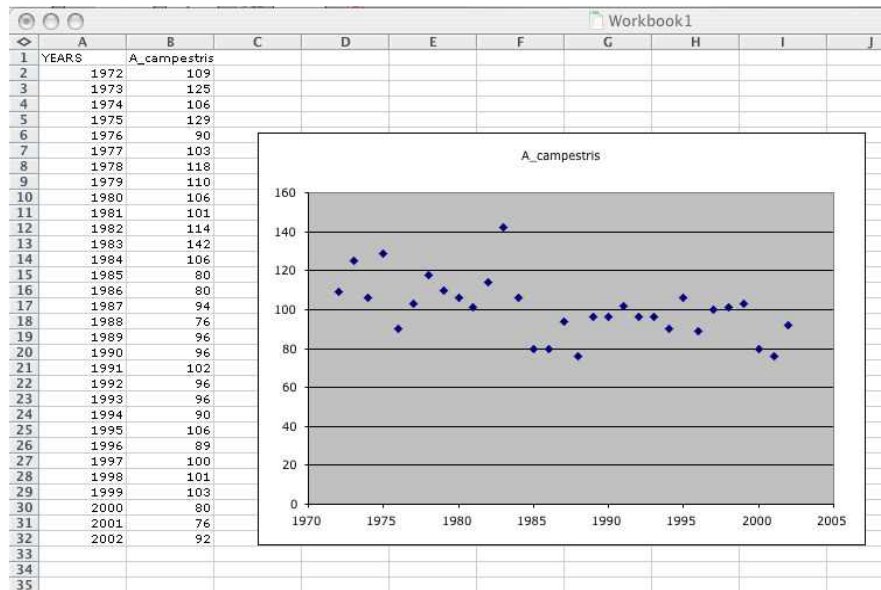
This graph is made from the data entered in Excel, as shown to the left:

Next, drag the mouse across your data so that the two columns of numbers are highlighted, then go up to the "Insert" drop down menu and choose "Chart." A menu will come up with many choices for types of graphs. You want "XY(Scatter)".

Once you have chosen the correct graph type, there are a number of options for the presentation of the graph. You can simply accept the defaults, and click "Finish" once you have highlighted the

"XY(Scatter)" choice.

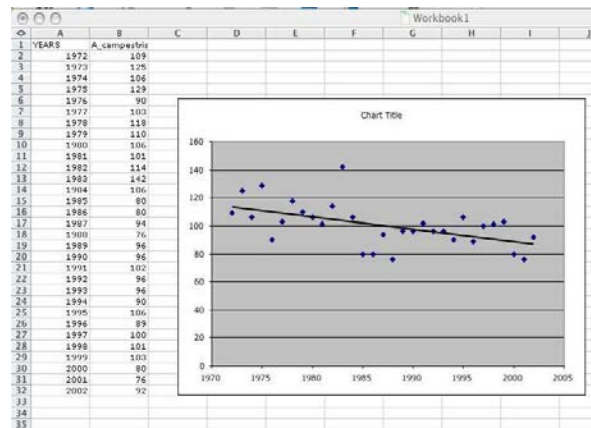
If you only have two columns of data in your worksheet (as shown in the picture above), Excel should then give you a graph of your data. Click on different parts of the data to change the way it looks.



## b) How to plot a line

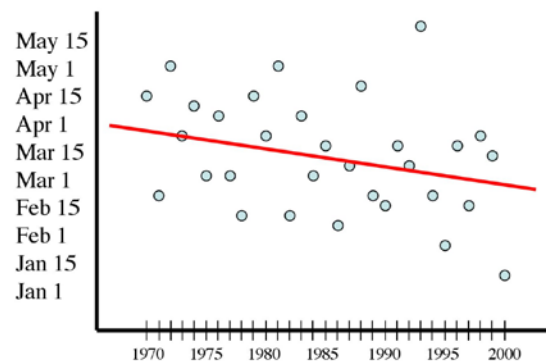
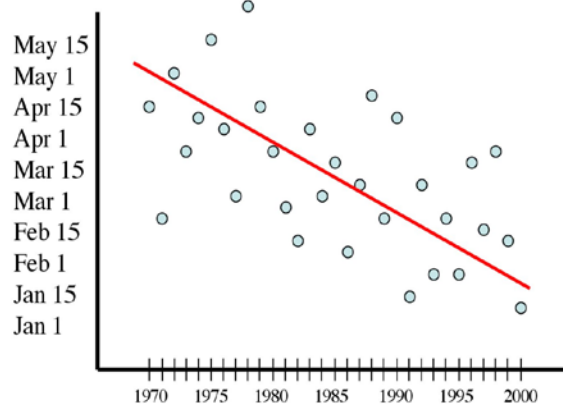
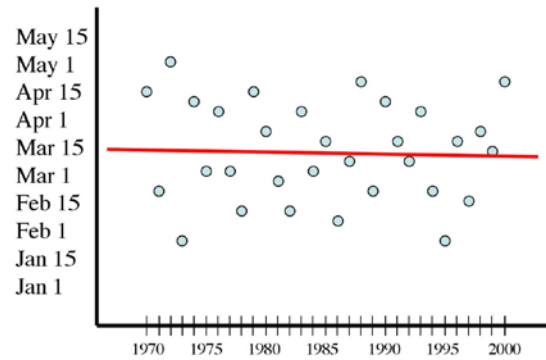
Next we want to put a line on our graph, which will help us better understand the data. Note that the goal is not to connect the dots, but to have a line that essentially shows an average through your data points. You can add a line like this to the scatterplot you already have by doing the following:

- i) click on the graph you have made so that it is highlighted
- ii) go up to the "Chart" drop down menu
- iii) choose the "Add trendline" option
- iv) a window will open with a number of graphing options, highlight "linear" and say "OK"



**c) How to perform a regression analysis**

Consider the three graphs below, which all show observations of butterfly phenology plotted against years (each dot represents the date of first flight in one year).



In the first graph, you see a line that is flat. This tells us that averaging across years there is no trend in butterfly emergence. In other words, the butterfly is neither emerging earlier or later over time. Compare that to the second two graphs, in which you see the line sloping down to the right. A sloping line suggests that a butterfly has been emerging earlier over the years (as previously discussed), but the slope of the line is different in those two graphs.

The line is sufficiently steep in the third graph that we might feel confident in saying that the butterfly is really emerging earlier each year. But what about the line in the second graph? It is possible that an early emergence in one or two years might by chance produce a line that sloped down just a bit -- in that case we would not want to conclude that the butterfly was really emerging earlier over time.

How can we distinguish between patterns like those shown in the second and third graphs? There is a subject called statistics that deals with this kind of question. Right now you are going to learn how to make Excel do one kind of statistical test called "regression." Your teacher may suggest other websites where you can learn more about statistics and regression, but for now let's just do the test and read the output.

In Excel, go to the "Tools" menu and look for "Data Analysis." If you don't see Data Analysis, you need to install it: go to Tools again, and choose "Add-ins." You will see a menu of choices, select "Analysis ToolPak."

Now you should be able to find Data Analysis under Tools. Select it (while you have your worksheet open with the data) and you will see another menu open up. Choose Regression. A new window will open with many choices. All you need to do is specify your x and y range... To do that, click in the box next to x-range and then move the mouse to your spread sheet and drag across the column of data that you want to be your x-data. Do the same for your y-data. Then hit OK (you don't need to change any of the other defaults).

You should see something like this:

graph.xls

	A	B	C	D	E	F	G	H	I	
1	SUMMARY OUTPUT									
2										
3	Regression Statistics									
4	Multiple R	0.52748957								
5	R Square	0.27824525								
6	Adjusted R Square	0.25335715								
7	Standard Error	13.1342384								
8	Observations	31								
9										
10	ANOVA									
11		df	SS	MS	F	Significance F				
12	Regression	1	1928.61653	1928.61653	11.1798531	0.00229299				
13	Residual	29	5002.73831	172.508217						
14	Total	30	6931.35484							
15										
16		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%	
17	Intercept	1852.63266	524.060372	3.53515122	0.00138972	780.808871	2924.45645	780.808871	2924.45645	
18	X Variable 1	-0.8818548	0.26374185	-3.3436287	0.00229299	-1.4212675	-0.3424422	-1.4212675	-0.3424422	
19										
20										
21										

The key part of that result is circled in red (you won't see a red circle on your computer). We call that the "P-value." If the P-value is less than 0.05, we conclude that the slope of the line on our graph is different from zero -- put another way, the butterfly is really emerging earlier or later (depending on which way the line is sloping). If the P-value is greater than 0.05, then we conclude that the pattern we see (perhaps a line with a shallow slope, as in the second graph above), was observed by chance (*and is not really different than a flat line*).

Another useful link to working with excel and producing graphs can be found at:

<http://www.hhmi.org/biointeractive/spreadsheet-data-analysis-tutorials>