Phenology and Climate Change

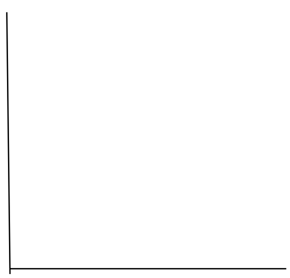
Overarching question: Based on observations of phenology, which species are most likely to be impacted by climate change?

Data Source: All data for this module were collected by citizen scientists and are available from the National Phenology Network website.

Learning objectives: In this lesson, you will manipulate data to make and interpret scatterplot graphs and regressions about the phenology of bumblebees and other organisms. You will make decisions about which data to use and evaluate your confidence in your conclusions given the nature of the available data.

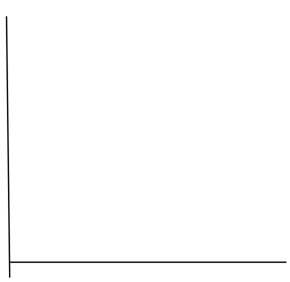
<u>Activity A: How has bumble bee emergence phenology changed over time?</u>
Rationale: One way to predict how a species will respond to climate change in the future is to examine at how it has responded to climate change in the past. The National Phenology Network provides data about the day of the year when the first siting of adult bumblebees occurred at a site in the years from 2010 to 2019. Six of these years are among the top 10 warmest years on record.

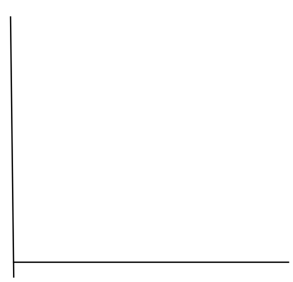
1. Sketch your predictions: What pattern would you expect to see for the relationship between phenology and year? Label your axes.



2. Explain your reasoning for your prediction.

3. Sketch other possible relationships you might find between phenology and year. What might be explanations for those relationships?





The data: Open the "Phenology_v_time" data file. The first tab contains all the records, and the second tab contains just the data for Minnesota. Each file contains a column with the year of record for a site and a second column with the day of the year when bumblebees were first recorded for the site.

4. Before you plot the data, what are the advantages and disadvantages of using the whole dataset and of using the data just from Minnesota?

5. **Plot the data**. Make a separate plot for each dataset, and sketch them below.

All Available Data

m=

R^2=

N=

Minnesota Sites

m=

R^2=

N=

6. If the data show a linear trend, it can be helpful to identify the slope so that we can compare graphs. To do this, add a trend line or conduct a linear regression analysis. The equation of the regression line is written in the form $y = mx + b$, where m is the slope and b is the intercept. Record the slope (m) for each graph above.

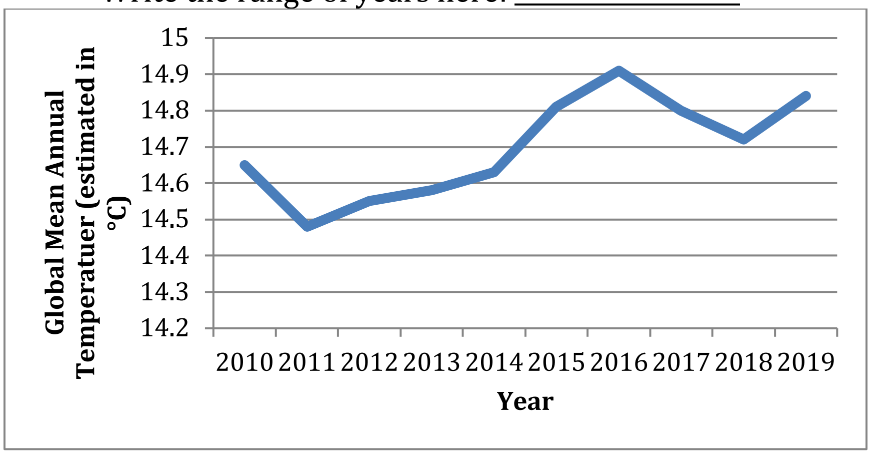
   The R-squared (R^2) is a statistic resulting from a linear regression analysis that describes the proportion of variation in the dependent variable explained by the independent variable. When $R^2 \sim 1$, the data form a perfectly straight line. As the data become more scattered from the line, R^2 decreases toward 0. Higher R-squared values indicate a stronger relationship between the two variables. Record your R^2 value above as well. Finally, record the number of data points used for each graph (N).

7. Describe the pattern you observed in words.

8. Identify several possible explanations for the national and MN patterns you observed.

9. Use the figure below, which shows estimates of the mean annual temperature between 2010 and 2019, to identify a time frame when temperatures were consistently and continuously increasing.

   Write the range of years here: ________________



Based on temperature anomaly data through November from https://www.ncdc.noaa.gov/cag/global/time-series/globe/land_ocean/ytd/11/1880-2019

10. Remake your plot with MN data from above to include only the range of years that you identified in the previous question. To do this, first sort your entire dataset by year. Then, select the data from the appropriate years to plot. Record and reflect on your results below.

m=

R^2=

N=

11. Now, hypothesize some environmental variables at a site that might help to predict the emergence phenology of bumble bees in a given year.

Activity B: What site variables best predict bumblebee emergence phenology?
Rationale: We have tested for change over time, but we can't be sure that changing climate is responsible for the patterns we observed. We can use environmental data recorded for each site to identify how much variation in bumblebee emergence phenology is explained by temperature or other climate-related variables.

Dataset. Open the "Regressions" dataset, make sure you are using the first tab, and look at the headings to identify the variables.

1. Circle your dependent variable in this list. Hypothesize how each predictor will relate to that variable.

Variable	Description
Latitude	Latitude of site; strongly relates to temperature and growing season length
Longitude	Longitude of site
Elevation_in_Meters	Elevation of site
Phenophase_Description	Type of observation: This dataset includes the date of the first adult activity observed and the date for the first flower visitation observed for each site reported in a year.
Mean_First_Yes_Year	Year of measurement
Mean_First_Yes_DOY	Day of Year when the first bumblebee activity was recorded.
Tmax_Winter	Maximum winter temperature during the year
Tmax_Spring	Maximum spring temperature during the year
Tmin_Winter	Minimum winter temperature during the year
Tmin_Spring	Minimum spring temperature during the year

2. Which of the variables in the dataset do you think will be the best predictor of emergence phenology? Sketch a graph of your predictions and explain why you chose this variable. Discuss your predictions with a neighbor.

Part 1. Data Selection
In this section, you will work together as a class to decide which subset of the data you should use to identify which environmental variable explains most variation in bumble bee phenology.

1. Decide as a class which predictor of bumble bee phenology to start with. Write your choice here:

2. You will create a series of regressions with a variety of subsets of these data, compare your results as a class, and decide which subset of the data to use for future regressions to compare the different predictors. Complete the data cleaning and subsetting steps below, make scatterplots and sketch your results. *If the data are linear,* conduct a regression analysis and record the results. Be ready to share your findings.

Data Cleaning. Some of the columns have missing data that are recorded as "-9999" in the data sheet. Identify some examples of these in the dataset.

- Copy the whole dataset into a new sheet.
- Identify a variable that you plan to test as a predictor of bumblebee emergence phenology. Sort the data by this variable.
- Any rows with -9999 for the variable of interest should come to the top.
- Delete these rows.

Data Subsetting. In activity A, we looked for patterns across years, and you should have discovered that subsetting the data to use records only from a specific region and time frame reduced the noise in the dataset, making it easier to detect trends. In this analysis, we are using predictors that vary across space and time. You will need to **decide** how to sort and subset the data to *control for undesired variables* (like time, for example, are there wet or highly variable years that are obscuring spatial patterns you might otherwise find?). You should also *evaluate the quality of the data*, and you may wish to subset the data to exclude suspect values.

3. Before you begin exploring, what variables might you want to **control** in your analyses? How could you subset your data to do so?

All Data:

m=

R^2=

N=

Subset 1:

m=

R^2=

N=

Subset 2:

m=

R^2=

N=

Subset 3:

m=

R^2=

N=

4. How did you decide how to subset your data? Explain your decisions.

For subset #	We only used records…	Because we…

5. Compare your results with those of others in your class. Decide together which subset of the data makes the most sense to use for all your future regressions. Explain your decision here.

Part 2. Analysis.

Now that you have selected a particular subset of the data to use, you can conduct a series of regression analyses to try to identify which environmental predictor best explains variation in bumblebee phenology. You should test at least two predictors and compare your results with those from the rest of the class.

Title:

m=

R^2=

N=

Title:

m=

R^2=

N=

1. Of the variables you tested, which are the best predictors of bumblebee emergence phenology? How did you decide these were the best?

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2. Compare your results to those from the rest of the class. Which variable is overall the best predictor of bumblebee emergence phenology? Record the results here.

Title:

m=

R^2=

N=

3. Use what you know about bumblebees (or what you look up) to make a hypothesis that explains your answer to number 2.

4. A. Using evidence, explain how important you think temperature is for bumblebee emergence.

B. How confident are you in your answer?

Not at all Confident 1 2 3 4 5 Very Confident

C. What would help you become more confident in your answer?

D. What other kinds of data would you like to test if they were available?

F. What questions do you still have?

Part C. How sensitive are different species to climate change? How does a species of my choice compare to bumblebees?

Rationale: In this activity, you will apply the skills you have learned to about analyzing a dataset for a different species. By comparing results across species, we can observe variable species responses to climate and predict which species show greater sensitivity to changing temperature.

1. Consider bumblebees, monarch butterflies, and emerald ash borers. Which species do you think would show greatest sensitivity to changing temperatures? Explain.

2. Sketch graphs that illustrate sensitivity of phenology to temperature changes, making one graph for each species. Order them from most to least sensitive. Be sure to label your axes (Phenology/Day of Year is on the Y axis.)

Most sensitive Least Sensitive

Species: Species: Species:

3. Because species often interact with each other in ways that are critical for their survival and/or reproduction, if interacting species show different sensitivities to climate change, they could end up with phenological mismatches. Give an example here of a possible mismatch that could occur with interacting species (be sure to explain why the mismatch might be likely).

4. Do you think you could use NPN data to predict the likelihood of a phenological mismatch? Explain.

5. The directions below will help you select and download a dataset. In order to be able to make useful comparisons, your class will need to make a number of decisions that are bolded below.

1. Go to the USA NPN Phenology Data Portal: https://data.usanpn.org/observations/get-started
2. Under "Get Started", choose "Site Phenometrics". This dataset provides information about sites and the date of first and last observations of organisms at the site. Click NEXT.
3. Under "Date Range", select the largest date range possible, from Jan. 1 1950-Dec. 31, 2019 (or latest year available). This will give you the full dataset and allow you to subset as appropriate for the question you are testing. For now, leave the data precision filter to 30 days to maximize the amount of data you get (though some dates of first sitings may not be very precise). Click NEXT.
4. Under "Locations", DO NOT click any buttons. This again will allow you to subset the data as appropriate based on the question you are asking. Click NEXT.
5. Under "Species" you can search the species/taxa for which there are records in the study. Use the filters to browse your choices. Do not make a selection or click NEXT yet.
6. **Decide as a class which kinds of organisms and phenological stage you want to study**. For example, do you want to study the flowering time of different kinds of plants, emergence of different kinds of insects, or a mix of pollinators and the plants they pollinate? Do you need to set any parameters on the **range** in which the organisms are found?
7. Once you know the criteria, decide which species or taxa you wish to study, check the box. Click Set Species, and then look at the Estimated Records in the box at the top right. Decide whether there are enough records to answer your question. If you are satisfied, click NEXT.
8. Under "Phenophases", select the appropriate phenophase of interest to your class. (For bumblebees, we selected "Activity" under "Animals"). Click Set Phenophases, check for the number of records. If you are satisfied, click NEXT.
9. Skip the Partner Groups page. Click NEXT.
10. Skip the Source Data sets page. Click NEXT.
11. Under "Output Fields", on the Climate Data Fields tab, select the variables necessary for your work. In order to make your data comparable with the *Bombus* data, you will want to use the same predictor we used for Part B. You may wish to download others as well. Click Set Optional Fields, check output, and when satisfied, click Next.
12. You probably do not need to download the ancillary data. The metadata tab on the left menu bar has any definitions you should need.
13. Click FINISH when you are satisfied, read the policies, check the box, and download the data.

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6. Based on your findings from part B, decide as a class on the specific tests you want to do so that everyone's analyses will be comparable.

Which variables will you compare?	Which subset of the data will you use?

7. What species did you choose?
8. Before you begin your analysis, learn something about your organism's biology and make a prediction. Do you think your species will be more or less sensitive to changing temperatures than bumblebees? Explain.

9. Clean and subset the data appropriately and conduct your analysis. Sketch your results below, and record N, m, and R^2 from your regression.

10. Based on the data you analyzed, do you think your species or bumblebees will be more affected by climate change? Refer to your graph above (Activity C#9) from Activity B2#2 to support your answer. Think carefully about what the N, m, and R^2 values mean with respect to the sensitivity of a species to temperature.

11. How might you explain this result?

12. How confident are you in your answer to question 9?

Not at all Confident 1 2 3 4 5 Very Confident

13. Consider the way the data were collected and the decisions you made during your analyses. What changes or additions would give you more confidence in your results?

14. Present your findings to your class. Record the patterns you notice when you compare the results for different organisms.

15. What new questions arise along with these observations?

Data Citation: USA National Phenology Network. 2019. Plant and Animal Phenology Data. Data type: Site Phenometrics. 1950-2019 all records. USA-NPN, Tucson, Arizona, USA. Data set accessed 28 October, 2019 at http://doi.org/10.5066/F78S4N1V