# Wildflower Phenology: A Case Study

Phenological Responses to a Changing Climate

## [Link to the visualization](https://huckley.shinyapps.io/PlantPhenology/)

## [Link to TrEnCh-Ed](https://trench-ed.github.io/#)

Learn more about this research:

* [The Primack Lab](https://www.rprimacklab.com/media)
* [Boston University Scientists in Concord](https://concordmuseum.org/online-exhibition/early-spring-henry-thoreau-and-climate-change/boston-university-scientists-concord/)
* [Tracking climate change with the help of Henry David Thoreau](https://www.elsevier.com/connect/tracking-climate-change-with-the-help-of-henry-david-thoreau)

## Objectives

* Describe changes in temperature over time.
* Analyze the impacts of climate on wildflower phenology.
* Test hypotheses about how the timing of flowering responds to temperature and propose potential mechanisms.
* Consider the ecosystem implications of phenology.

## Cross-cutting concepts -- *Next Generation Science Standards*

* Patterns
* Cause and effect
* Stability and change

## Cross-cutting concepts -- *Other*

* Change vs variability
* Data reasoning

## Standards

Life Science Standards (LS)

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| HS-LS2-2 | Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. |

Advanced Placement Environmental Science

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| **Learning Objectives** | **Essential Knowledge** |
| 1.2 - Describe the global distribution and principal environmental aspects of terrestrial biomes | * **ERT-1.B.4** -The worldwide distribution of biomes is dynamic; the distribution has changed in the past and may again shift as a result of global climate changes. |

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| 2.6 - Describe how organisms adapt to their environment. | * **ERT-2.H.1-** Organisms adapt to their environment over time, both in short- and long-term scales, via incremental changes at the genetic level. * **ERT-2.H.2** - Environmental changes, either sudden or gradual, may threaten a species’ survival, requiring individuals to alter behaviors, move, or perish. |
| 3.1 - Identify differences between generalist and specialist species. | * **ERT-3.A.1 -** Specialist species tend to be advantaged in habitats that remain constant, while generalist species tend to be advantaged in habitats that are changing. |

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| 9.4 - Identify the threats to human health and the environment posed by an increase in greenhouse gases. | * **STB-4.E.1 -** Global climate change, caused by excess greenhouse gases in the atmosphere, can lead to a variety of environmental problems including rising sea levels resulting from melting ice sheets and ocean water expansion, and disease vectors spreading from the tropics towards the poles. These problems can lead to changes in population dynamics and population movements in response. |

## Instructions

### Background

1. Define phenology.
2. Other than the first flowering date, what are three phenological events for plants?
3. Why is flowering an important phenological event?

### Temperature and First Flowering Date

The app includes a figure that will allow you to look at changes in temperature over a period of 122 years (1893-2015). The first exercise will walk you through a number of tasks so that you can build mastery of the learning objectives.

1. What does each data point show?
2. What does the blue trendline show?
3. The equation in the corner of the graph describes the relationship between year and temperature. What does the R2 indicate?
4. Keeping the range of years from 1893 to 2015, select four different months and watch how the graph changes. The months you select should be months you consider to be representative of each of the four seasons: winter, spring, summer, and fall.
   1. Why is the y-axis different in each of the four months you selected?
   2. How does the x-axis change between the four months?
   3. In which month was the slope of the blue trendline the steepest? Interpret this result by describing the relationship with temperature over time.
   4. In which month was the p-value the largest? Interpret this result by describing the relationship with temperature over time.
5. Plot annual average temperatures (find this at the bottom of the list of months) across the entire time period.
   1. Around how much has the average annual temperature increased since the 1890s?
   2. If the current trend continues, what will the average annual temperature in Concord be in 2075?
6. The timing of flowering is highly dependent on temperature. Hypothesize which months are likely to have the largest effect on flowering phenology and explain your reasoning.

### Relationships between temperature and First Flowering Date (FFD)

1. Create scatterplots for all species, showing annual temperature on the x-axis.
   1. For which two species does phenology advance with warming (you see a clear negative slope)?
   2. What do these species have in common?
2. Create scatterplots for all species, showing January-April temperature on the x-axis.
   1. Now, which species have flowering phenologies that advance with warming?
   2. Keeping in mind the months that warmed the most over the years, what can we conclude about the flowering dates?
3. Propose a hypothesis for why some species show higher or lower slopes when you plot FFD against temperature. (There are many possibilities!)

### Synthesis

1. What impacts could changing FFD’s have on other species (including animals) in the ecosystem?
2. How could the data used in this study be improved? What other sources of data can be used to study changes in phenology or abundance of species over time?