# Grasshopper Resurvey: Phenological responses to climate change

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

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

Learn more about this research:

* [What 13,000 Dead Grasshoppers Can Tell Us About Climate Change](https://www.kunc.org/post/what-13000-dead-grasshoppers-can-tell-us-about-climate-change#stream/0)
* [Grasshoppers & Climate Change](https://www.youtube.com/watch?v=V25aXrBVFj0)
* [Resurrecting the Work of Gordon Alexander: Grasshopper Communities and our Changing Climate](https://entomology.umd.edu/news/-resurrecting-the-work-of-gordon-alexander-grasshopper-communities-and-our-changing-climate)

## Objectives

* Understand how temperature influences insect development rate.
* Use this understanding to examine shifts in seasonal timing (phenology) in response to cool and warm seasons.

## Core concepts -- *BioCore*

* Ecology & Evolutionary Biology: Evolution
* Ecology & Evolutionary Biology: Information Flow
* Ecology & Evolutionary Biology: Systems

## Instructions

First, read through the Grasshopper Resurvey introduction in the visualization. This will give you the required background information for these questions.

### Part A: Exploring Development Index Data

In this first exercise, you can generate figures that all have the same general structure. On the y-axis, you’ll see values for development index. On the x-axis, you can select between Season GDDs or Day of Year (in Day of Year units, Jan 1=1, and Dec 31=365). Finally, you can select one or more grasshopper species and one or more sites (elevations) to plot. The resulting lines will be in the shape of an upward trajectory that eventually levels off. Each line represents one population of grasshoppers (one species living at a particular elevation in a particular year). The line slopes upwards because the population as a whole matures over the course of the season, so its development index increases. Finally, when all individuals are adults, the line levels out. Dashed lines represent historical data and solid lines represent resurvey data, while bluer colors indicate cooler years and redder colors indicate warmer years.

1. For this question, look at all of the species plots
   1. What is each graph showing?
   2. What trends and patterns are you noticing for each species?
   3. In general, how does phenology differ between cool and warm years?
   4. How does phenology differ between low and high elevations?
2. Select the Aeropedellus clavatus to plot.
   1. How does phenology differ between historic and resurvey years for A. clavatus? (Hint: The closer a line is to the left of the panel, the earlier in the season development begins, and vice versa.)
   2. Why might this be?
3. Next, select just the Melanoplus sanguinipes.
   1. How does phenology differ for high vs. low-elevation populations of M. sanguinipes? (Hint: The steeper the line, the faster development occurs.)
   2. Why might this be?
4. For this question, just look at the time periods of 2007 and 2010.
   1. How does phenology for M. boulderensis differ in 2010 vs. 2007?
   2. What about M. dawsoni?
   3. Why might this be?

### Part B: Exploring relationships between time, growing degree days, and grasshopper phenology

In the second exercise, you can again select one or more grasshopper species and one or more sites (elevations) to plot. Two kinds of figures will be generated: On the left, you’ll see data showing which day of the year your chosen population reached adulthood in relation to how warm the growing season was that year. For example, a data point located at 200 on the x-axis and 180 on the y-axis reflects a population that reached adulthood on day 180 in a year when the summer season had 200 growing degree days.

On the right, you’ll see data showing how much accumulated heat your chosen population had experienced before reaching adulthood, again in relation to how warm the growing season was that year. For example, a data point located at 300 on the x-axis and 200 on the y-axis reflects a population that reached adulthood after it had experienced 200 growing degree days, in a year when the summer season had 300 growing degree days. A relatively horizontal line suggests that the population tended to reach adulthood after experiencing the same amount of accumulated heat, no matter how warm or cool the season was.

1. Plot the data for all species at site 2591m.
   1. In cool vs. warm years, do the dates at which grasshoppers reach adulthood change?
   2. Does the amount of accumulated heat they experience change before reaching adulthood?
   3. Is this different for early vs. late-season grasshoppers (see the **Grasshopper traits** table in the reading above)?
2. Plot the data for the species Melanoplus dawsoni.
   1. How does the date at which M. dawsoni reaches adulthood change with seasonal warmth?
   2. Is this different at low vs. high elevations? Explain why this might be.
3. How does the amount of accumulated heat M. dawsoni experiences before reaching adulthood change with seasonal warmth?
   1. Is this different for early vs. late-season grasshoppers?
4. Plot the data for the species Chloealtis abdominalis
   1. How does the amount of accumulated heat experienced by C. abdominalis when it reaches adulthood change with seasonal warmth?
   2. Is this different at low vs. high elevations? Explain why this might be.