# 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.

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

* Patterns
* Cause and effect
* Scale, proportion, and quantity
* Stability and change

## Cross-cutting concepts -- *Other*

* Change vs variability
* Data reasoning

## Standards

Life Science Standards (LS)

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| HS-LS2-6 | Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. |

*Advanced Placement Environmental Science*

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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. |

## Instructions

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

### Background

1. Define phenology.
2. What is diapause?
3. What organism in this reading spent months in diapause?

#### Colorado Grasshoppers: Then and Now

1. Define elevational transect.
2. Extra question: Summarize Nufio’s journey to science.

#### Grasshopper traits

1. Which species are early season species?
2. Which species are late season species?

#### This visualization

1. What is a growing degree day (GDD)?
2. How are GDDs different from season GDDs?

### Analysis

#### 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 the 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: Change the “variable for columns” to Year and select some historic years and some resurvey years. 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.