## Grasshoppers and Climate Change Activity – College level lab

Nearly 50 years ago, Dr. Gordon Alexander surveyed the grasshopper communities at several life zones along an elevation gradient in the Rocky Mountains of northern Colorado. Four of these surveyed sites were near weather stations that have collected daily temperature data over the last half century. Since 2006, a new resurvey program has been established to examine how climate has changed over the last half century at each life zone and in turn, how this warming has impacted the phenology, biology and behavior of associated grasshoppers.

### Goals of Exercise

i) To introduce students to the effects of climate change on organisms, the life zone concept, and growing degree days (GDDs)

ii) To allow students access to actual climate and grasshopper survey data to evaluate recent climate change and its effects on insect and plant development

iii) To provide students the tools and concepts necessary to understand and evaluate how future climate change may affect the development, number of generations and distribution of organisms

### Summary of steps of activity

1) To increase lab participation, students will need to read the on-line pre-lab materials and complete the provided pre-lab questions
2) In lab, instructors will provide a short presentation on climate change and Alexander's survey to set the context for the exercise (presentation provided below)
3) During lab, students should be placed into 4 groups (with 4-5 students in each group) that correspond to one of four life zones (plains, foothills, montane and subalpine). Each group will address three broad questions:
    - i) How has climate changed along an elevational gradient in the Rocky Mountains of Northern Colorado?
    - ii) How have grasshopper communities responded to non-uniform warming along the elevational gradient?
    - iii) How might grasshopper phenology be affected by future estimates of climate change?
4) Once students have worked through the lab, they will have an opportunity to address novel questions that test their grasp of the key concepts above. Namely, they will address how changes in GDDs can affect the number of generations organisms can undergo during a season as well as their spatial distributions.

**Detailed steps of activity**

**Step 1.** A Prelab is provided via the lab intro page to increase student participation and to introduce them to important concepts they will use in the lab.

**Step 2.** Begin the lesson by presenting the talk **"Grasshoppers and Climate Change"** provided as a PowerPoint presentation below. This talk provides the basic context for the activities and there are notes associated with each slide page for instructors. The second PowerPoint presentation allows instructors to guide students through each activity (see below). Currently, the presentations may be lengthy as the goal is simply to provide access to information that could be used to create a presentation that best meets the needs of your course. That is, feel free to shorten or modified the lectures to best meet your specific needs and teaching style.

The Alexander Resurvey Project and climate change INTRO

Grasshoppers and climate change Activity

For a more detailed introduction and background to this project please see the following manuscripts as well as the broader links associated with this web site.

Nufio, C.R., C.R. McGuire, M.D. Bowers and R. Guralnick. 2010. Grasshopper community response to climatic change: variation along an elevational gradient. PloS one. Vol. 5, e12977 http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0012977

Nufio, C.R, Lloyd K. J., Bowers M. D., and Guralnick, R. 2009. Gordon Alexander, Grasshoppers, and Climate Change. American Entomologist. 55:10-13

*Suggestion*: This talk and lab may follow other activities that may supplement or better set up this system given your class focus. This activity may, for example, follow other modules on life zones, climate change or the effects of climate change on organisms. As such, the students could use their understanding of previous concepts to interpret their findings.

**Step 3.** Following the talk, students should be broken up into four groups (of 4-5 students), with each group being in charge of processing the data associated with a given site. The four sites are Chautauqua Mesa, A1, B1 and C1 and they represent the plains, foothills, montane and subalpine life zones, respectively. If there are more students than can fit in 4 groups, you can easily create independent groups that can work on similar sites. You will just need to take this into account in activity 2 below as you will need to have enough sampling bins.

**Part 1. How has climate changed along an elevational gradient in the Rocky Mountains of Northern Colorado?**

**Details of Activity:** Students are provided **Figure 1** that shows the average yearly temperatures associated with each of the 4 life zones in this study. The students are also provided with **Figure 2** which shows the average daily temperatures during March-August at the different life zones during the 10 years (1955-1964) around the time of the initial grasshopper surveys. The average temperatures during the months of March-August are of special interest as temperatures during March become high enough to allow grasshoppers to develop (see Growing degree days) and by August, all species of interest have become adults.

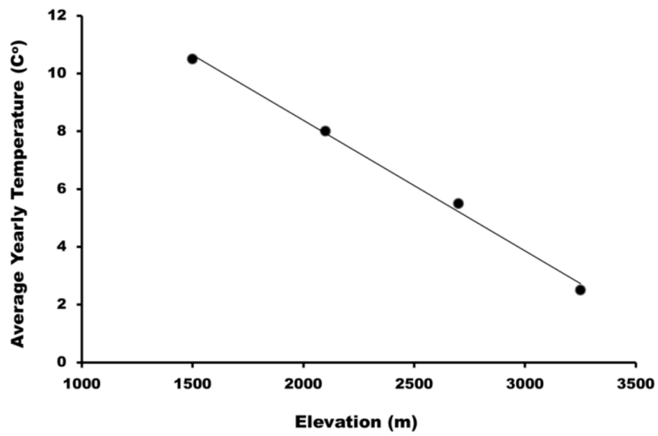


**Figure 1.** Average yearly temperature and elevation along a high plains to subalpine gradient in Northern Colorado.

An instructor should introduce the students to the provided **Figure 1** (it can be found in the first Powerpoint presentation above) and can ask them to interpret the figure as a class. Why does the average temperature decline with elevation (as altitude increases, air becomes thinner and is less able to absorb and retain heat)? How might this affect the amount of energy that is available to plants and insects that are developing? What is happening to precipitation? How might the average temperature and precipitation help explain the types of communities associated with the different life zone?

Students will then use **Figure 2** to determine how temperatures have changed over the last 50 years at the 4 different life zones. Students are provide an Excel sheet "**Yearly Averages and Max & Min Data**" to calculate the average March-August temperatures associated with the recent survey (1999-2008) and they will work within their groups to determine how the average daily temperatures have changed since Alexander's original study. A general discussion should be had to make sure the students realize that warming has been non-uniform and to be sure the numbers agree across the groups. Have the students make predictions within their groups as to how they might expect grasshopper phenology to change along the gradient (Part 1, question 2).

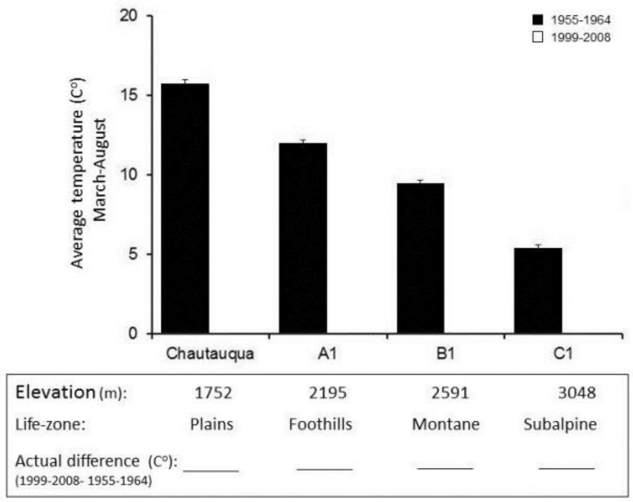


**Figure 2.** The average daily March to August temperatures that occurred during 1955 to 1964.

**Part 2. How have grasshopper communities responded to non-uniform warming along the elevational gradient?**

During 1959-1960, Gordon Alexander and his team surveyed grasshoppers on a weekly basis and recorded the species that were present and their developmental stages (grasshoppers have 5 juveniles stages before they reach adulthood). In this exercise, students will use Alexander's survey data, notably the earliest date to adulthood for each species during1959-1960, to determine the degree to which grasshoppers have advanced their timing to adulthood during the last 50 years.

**Details of Activity:** For this activity, instructors must create collecting bins that represent each of the weekly surveys conducted during the 2006 or 2007 depending on the site. These bins will need to be populated by printing and cutting out provided images of the different grasshopper species that occur at these sites. The number and species that will be placed into each collecting bin is available in the key provided below. While a teacher may deviate from the number of copies of a given species placed in each bin, in order for this activity to work, the actual species placed within each dated collecting bin must be correct.

Key to Grasshopper Surveys    Labels for Collecting Bins

The necessary images and number of sheets to print are available here.

| | | | |
|---|---|---|---|
| Chautauqua Mesa (Plains, 1752 m) | A1 (Foothills, 2195 m) | B1 (Montane, 2591 m) | C1 (Subalpine, 3048 m) |

The field guide students will use to identify the grasshopper species present within each collecting bin is available below. Colored keys are essential and two keys per group works fine. Laminating the keys and grasshopper cards would allow these to be used by many classes. NOTE THAT ALL GRASSHOPPER CARDS WITHIN THE BINS ARE ADULTS AND ALL GRASSHOPPER IMAGES IN THE KEY ARE ADULTS AS WELL.

Field guide to Grasshoppers

**Running the Activity.** Students in the different groups will be given roughly 5 sampling bins associated with their assigned sites. These bins reflect the grasshopper species that were surveyed during each of the collecting events during 2006 or 2007 at a given site. Each numbered bin has an ordinal date (ordinal day 1 being January 1st, ordinal day 365 being December 31st) and the goal is to have the students determine the first ordinal date in which a grasshopper species became an adult during the current survey. Once they determine the ordinal date to adulthood for each species, they will compare this date to the earliest time to adulthood during the 1959-1960 survey to determine whether a species has advanced their timing to adulthood and if so, by how much. Relative changes in the timing to adulthood will differ across the sites. The use of sampling bins will allow the students to imagine how the data was collected and processed.

IMPORTANT: Please note that students will not encounter juveniles but may encounter species that are not species in the study (they are accidentals or uncommon species at the site). These species were added to make the surveys a little more realistic and to balance the number of species sorted by the different groups.

After each group has determined the changes in timing to adulthood associated with their site and had a chance to talk about their findings within their group, they will present their findings to the class and talk about their conclusions. It is recommended that **Table 1** be available on the board so that each group can provide their results to the class as a whole. After the last group presents, the students can discuss whether their initial predictions regarding their ideas about changes in grasshopper phenology were supported. What are the take home messages that the student are left with when interpreting all the findings together?

**Part 3. How might grasshopper phenology be affected by future estimates of climate change?**

Grasshopper advancement to adulthood at different sites can largely be attributed to a more rapid accumulation of heat energy (Growing Degree Days) that occurs in warm years. Using the actual temperature data at each site students will predict future changes in grasshopper phenology based on different warming scenarios at their given site.

Before the students begin this section, it is recommended that the instructors provide a brief presentation on the GDD concept, how GDDs are calculated and why they are important to ectotherms. This information is provided in the second PowerPoint presentation titled "Guide through the Laboratory Exercise".

**Details of activity:** Using actual climate data from each site (the average min and max for each ordinal date), students will calculate and graph how GDDs accumulate at each site. This data is available as an Excel sheet next to the student worksheets (titled "**Yearly Averages and Max & Min Data** "). Students will need to understand the formula for determining how GDDs accumulate at their given site.

Draw **Figure 4** on the board and have each group draw the GDD accumulation pattern associated with their site. Make sure each group notes when GDDs begin to accumulate, when GDDs stop accumulating and the total number of GDDS that accumulate by the end of the season.

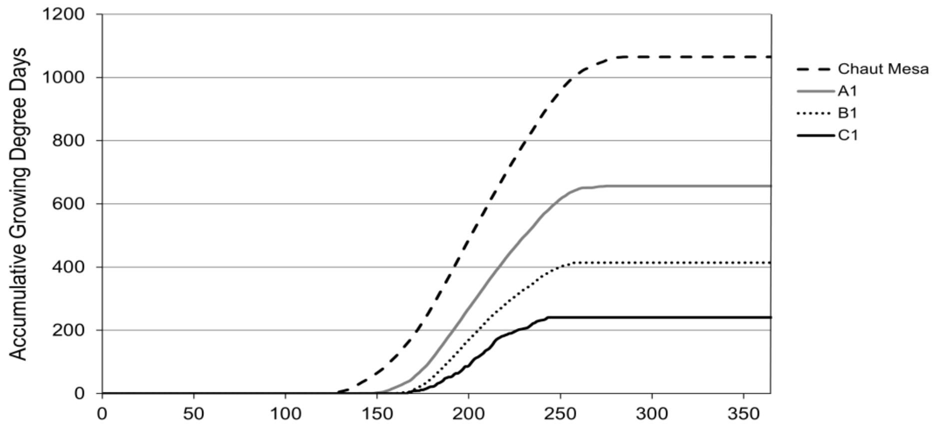


**Figure 4.** This figure illustrates the GDD accumulation patterns at each of the 4 sites. Notice that GDDs begin accumulating later in the season as one moves up in elevation and that GDD accumulate for a longer time period at lower elevations; making the season longer at lower elevations. Notice also that the number of GDDs that accumulated by the end of the season are higher at lower elevation (Chaut Mesa 1065, A1 656, B1 414, C1 241 GDDs).

There are instructions in the lab handout to help them understand how GDDs are calculated and how they can use Excel to make these calculations. A full key to the required Excel equations is provided in the key above.

After students determine how GDDs accumulate at their sites (and at the other three sites; **Figure 4** above), they will then estimate how GDDs may accumulate at their sites given predicted warming scenarios of plus 1, 3, and $5^0$C by 2100. **Figure 5** shows an example of what this figure with climate change predictions would look like at site B1. Students will use this information to determine how the phenology of a given grasshopper may change given the different warming scenarios.

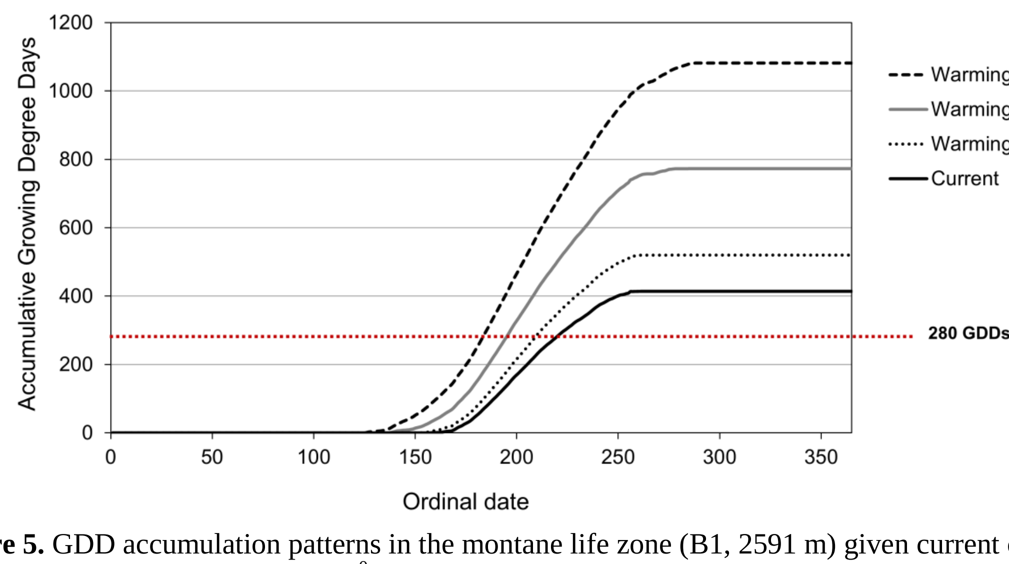


**Figure 5.** GDD accumulation patterns in the montane life zone (B1, 2591 m) given current climatic conditions and projected 1, 3, and 5 $^0$C increases by 2100. The grasshopper of interest requires 280 GDDs at B1, so students can either use the graph to estimate the change in the timing to adulthood or they can look directly at columns AG-AK to determine the exact date associated with 280 GDDs given each warming scenario.

**Students should email the worked out Excel sheet to their group members. This worked out Excel sheet will help them address the questions posed in their homework.**

## HOMEWORK

Using the knowledge the students have acquired throughout this lab, the students will determine how changes in GDDs can affect the number of generations and distributions of species given future climate change. All equations the students will require to answer these questions are available in the Excel and lab sheets.