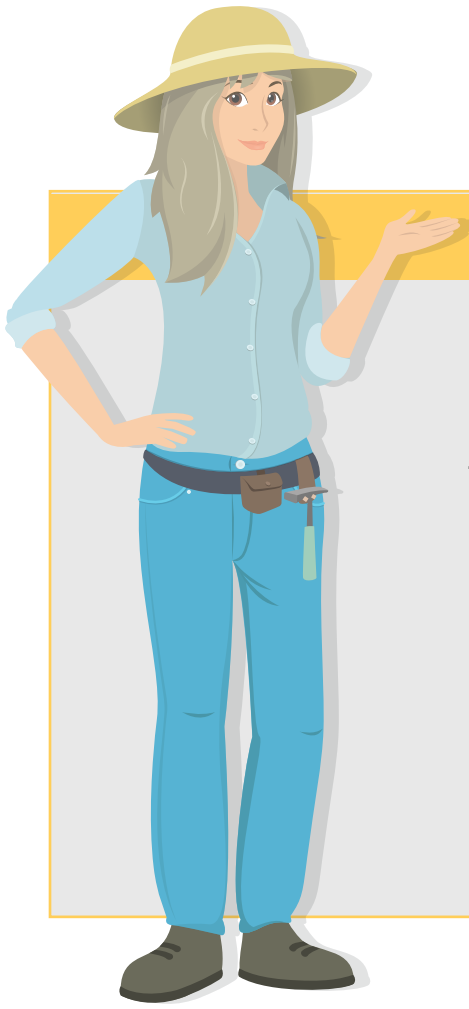


Overview

Digital RMBL's Warming Meadow Experiment opens up the world of experimental field science at Rocky Mountain Biological Laboratory to learners around the world. These interactive e-learning modules invite students to consider the factors related to setting up a field experiment, and to explore and apply datasets from this long-term experiment (twenty-three years and counting!). Through these modules, students will have the unique opportunity to think and make decisions like a field scientist without even leaving the room.

Context for Use

This learning experience was designed for an undergraduate science course and is open to students from all disciplines. It is highly adaptable to other classroom situations, including motivated high school classes or graduate level classes. The students should already have a conceptual understanding of the scientific method, climate change, and statistics before beginning this module. The module can be implemented in a single 50-minute class period, or adapted to extend through several class periods.

Learning Goals

This learning experience develops students' critical thinking skills by encouraging them to:

- Ask scientific questions.
- Compare disparate datasets.
- Use statistics to strengthen arguments.
- Understand experimental design.
- Conduct open-ended inquiries.
- Construct arguments from data.
- Draw conclusions from research papers.

More specifically, after completing these modules, students will be able to:

- Identify the purpose and design of the Warming Meadow experiment.
- Differentiate between the heated and control plots of the Warming Meadow experiment.
- Interpret datasets from the Warming Meadow experiment to draw conclusions.

Datasets

The datasets—aboveground carbon, soil carbon, and snowmelt date—used in this learning experience are provided by Dr. John Harte, UC Berkley and are based on the annual summary data obtained from the control and experimental plots of the Warming Meadow.

Teaching Strategy

In this section, there are suggestions for effectively using the learning resources for the Warming Meadow Experiment. The teaching strategies provided here are split into three sections: Introduction, Interaction, and Exploration.

Introduction

Before you use the interactives, introduce the topics through pre-reading assignments and pre-assignment lecture topics.

Pre-reading Assignment for Students

- "Climate change may spur loss of mountain meadows, forest shifts" by Sarah Gilman for the Aspen Daily News, July 29, 2007

Pre-assignment Lecture Topics

- Locate RMBL and the Warming Meadow (38°57'26.16"N, 106°59'7.51"W) on a map. Check out the satellite images of the area from Google Earth. Note the topography (both natural and artificial) surrounding the Warming Meadow.

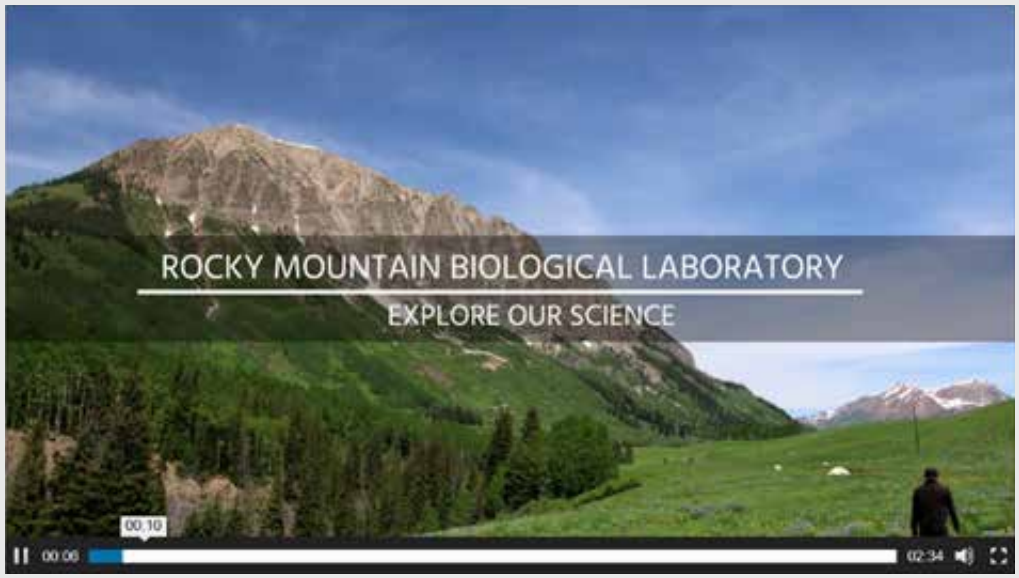
- To familiarize your students with the environment around RMBL, show Sarah Rudeen's slides of RMBL plants, animals, and landscapes.
- Explain basic concepts of inferential statistics—dependent variable, independent variable, scatter plots, and regression analysis—as well as the concept of "statistical significance."
- Check out billy's Data Visualizer, loaded with billy barr's phenology observations and climate summaries. This tool could be useful as a demonstration during lecture or as a first step for students to become familiarized with other useful RMBL data.

Interaction

Use the interactives in this learning experience to guide learners through the design and set-up of the Warming Meadow Experiment as well as the analysis of key parameters that influence climate change.

To access the premium content, you will need to log in and set up a Digital RMBL account. See the section below for more details.

1. View the Introduction Video together as a class. (*5-10 minutes*)

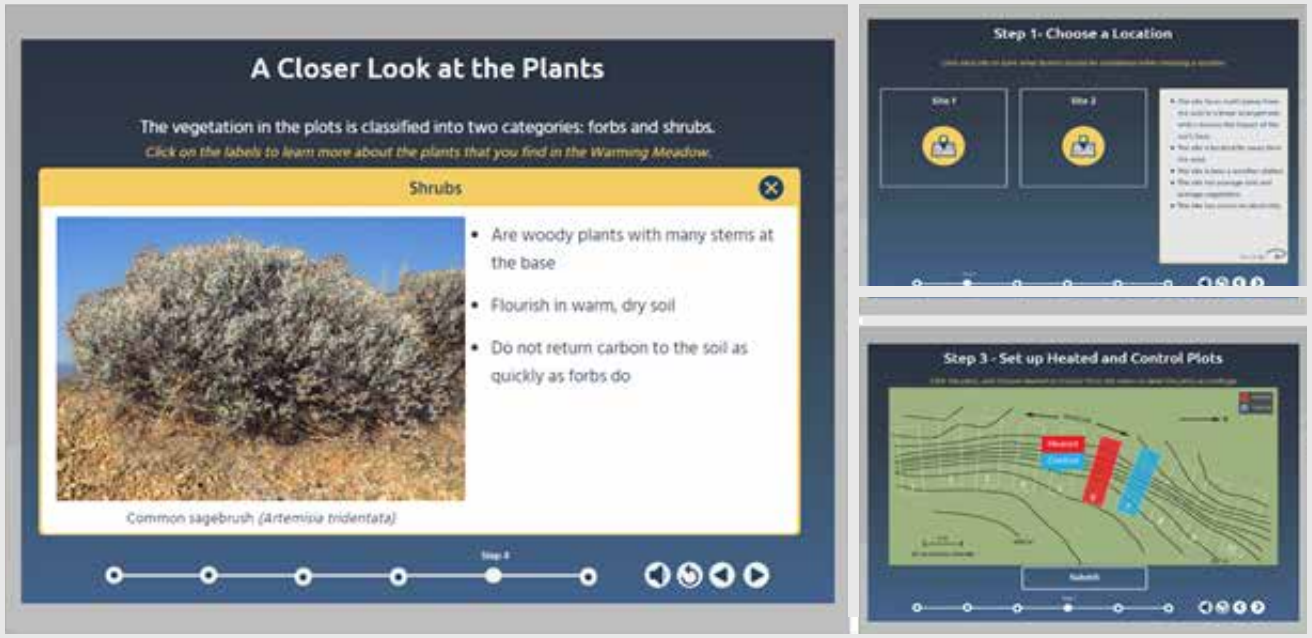


Suggestions for follow-up questions:

- How do you expect the world's climate to change over the next 100 years if global warming continues? How would climate change of this magnitude affect humans? Animals? Vegetation?

The two interactive modules can be experienced in groups in the classroom or designated as individual assignments. Follow up with a discussion in class.

2. Interact with the Design the Experiment section. *(20 minutes)*



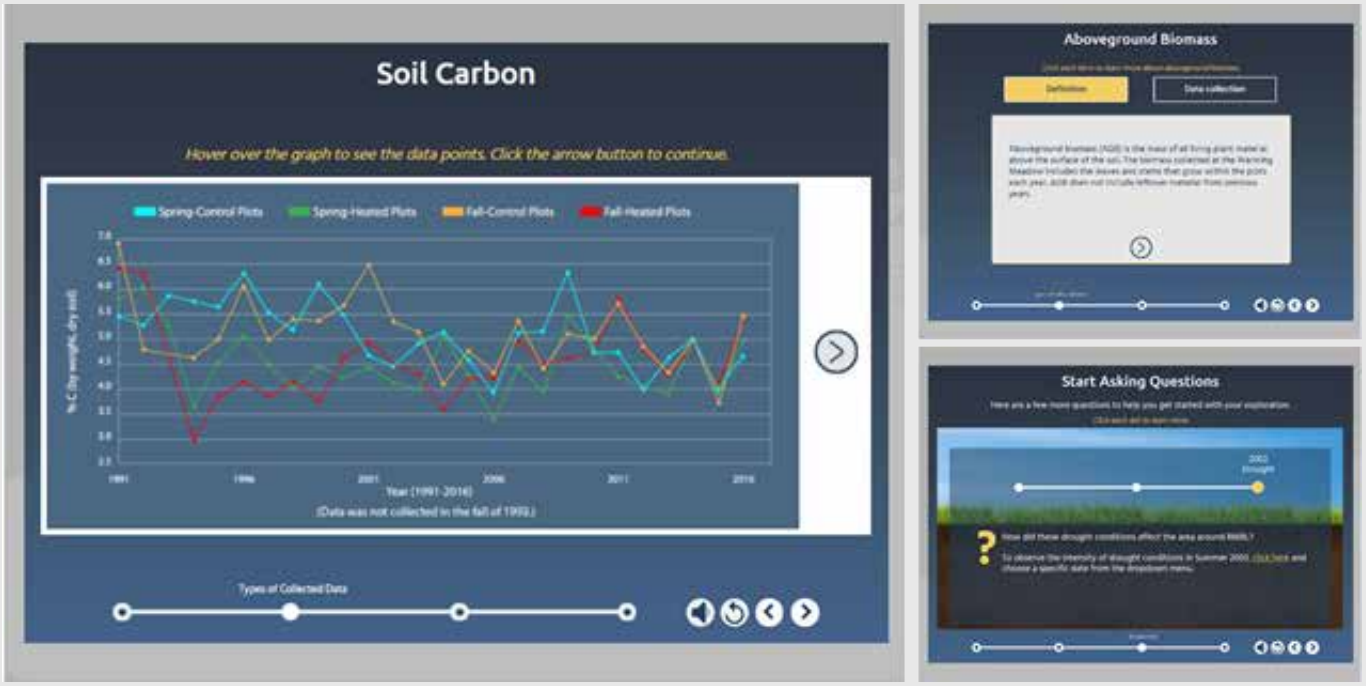
The first interactive introduces students to the Warming Meadow Experiment by traveling back in time to help Dr. John Harte make decisions about how to set up the experiment. Students help choose a location that maximizes the cost-benefit analysis, determine the most appropriate plot size, differentiate between heated and control plots, and explore the topography and vegetation of the plots.

Suggestions for follow-up questions:

- What were John Harte's original goals for the Warming Meadow Experiment?
- Describe the set-up of the Warming Meadow Experiment.
- If you were to set up a similar experiment in a different location, what would be the most important factors to consider?

- What is the difference between the heated and control plots of the Warming Meadow Experiment? Why are both necessary? What do you predict will be the difference in the data that is gathered from these plot treatments?
- Describe the difference between shrubs and forbs.

3. Interact with the Analyze the Data section. *(20 minutes)*



The second interactive walks the students through the interpretation of datasets from the Warming Meadow to draw conclusions about the effects of climate warming. Students take a closer look at three types of data collected from the Warming Meadow: aboveground biomass, soil carbon, and snowmelt date. In addition to learning about what each type of data is and how it is measured, students study line graphs and make inferences about the patterns shown.

Students are also encouraged to begin generating their own questions about the Warming Meadow.

Suggestions for follow-up questions:

- What trends and inferences did you discover in the aboveground biomass data?
- What trends and inferences did you discover in the soil carbon data?
- What trends and inferences did you discover in the snowmelt date data?
- What could cause the similarities and differences in the data from year to year?
- What else would you need to know to evaluate the patterns you see in the data?
- What impact does the open system have on the Warming Meadow Experiment? How might changing abiotic conditions, like temperature or precipitation, affect conditions in the control or heated plots?
- How did the drought conditions of Summer 2003 affect the Warming Meadow?
- What other response variables would you like to measure in the Warming Meadow?

Exploration

To extend the learning experience beyond the interactives, encourage learners to make their own discoveries using the raw data from the Warming Meadow as well as the RMBL Publication database.

4. Download the Warming Meadow dataset. Observe the emerging patterns and draw your own inferences. We recommend that students work in small groups (2-3 students) to generate basic statistics and perform regression analysis on the datasets and then report back to the class with their findings.

5. Read key research papers that have been published about the Warming Meadow Experiment through the years:

a. Harte J, Shaw R 1995. Shifting dominance within a montane vegetation community: results from a climate-warming experiment. Science 267:876-880

b. Saleska SR, Shaw M, Fischer ML, Dunne JA, Holman ML, Still C, Harte J 2002. Plant community composition mediates both large transient decline and predicted long-term recovery of soil carbon under climate warming. Global Biogeochemical Cycles 16(4):1055

c. Harte J, Saleska S, Levy C 2015. Convergent ecosystem responses to 23-year ambient and manipulated warming link advancing snowmelt and shrub encroachment to transient and long-term climate–soil carbon feedback. Global Change Biology 21:2349-2356

- Note the hypotheses and conclusions that have been made by RMBL scientists over the years.

One Learner's Experience

"I liked the fact that it was in a story format and each point built on the previous points. The interactives were thoughtful and appropriate. The introduction video was short and effective in conveying what was about to follow. The videos have stunning imagery. I could place the video on mute and watch it on loop. Having narration throughout is engaging. The overall flow is nice; I like how one thing leads into the other without missing something or abrupt jumps. The 'types of collected data' section that requires making inferences from the data is good."