**Adapted from: The Biology of Climate Change: The effects of a changing climate on migrating and over-wintering species at a high-elevation field station**

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**THE ECOLOGICAL QUESTION:**

How does climate change affect the phenology of species? How might changes in temperature impact ecological interactions?

**ECOLOGICAL CONTENT:**

Climate change, environmental variation, phenology, species interactions, trophic mismatch

**WHAT STUDENTS DO:**

Students engage with findings from long-term environmental and phenology data sets collected at the Rocky Mountain Biological Laboratory, a high-elevation field station in Colorado, to explore the effects of climate change on the phenology of migrating and hibernating species. After becoming familiar with the people involved with the data collection, and organisms studied through videos and discussion, students **explore** figures and regressions from Inouye et al. (2000) based on those data **to understand the value of regressions in detecting patterns and possible mismatches of animal and/or plant phenology (e.g. marmots emerge before plants grow big enough to be nutritious)**. Students can then build upon their initial understanding by **exploring data through the National Phenology Network (NPN), choosing a trophic relationship, and exploring the possibility of mismatches. Finally, students present their results in the form of a “poster” drawn on the board and discuss with the class their findings.**

**STUDENT-ACTIVE APPROACHES:**

[Cooperative learning](http://tiee.esa.org/teach/teach_glossary.html#cooperative), critical thinking, [guided inquiry](http://tiee.esa.org/teach/teach_glossary.html#guided), [open-ended inquiry](http://tiee.esa.org/teach/teach_glossary.html#openended)

**SKILLS:**

* Interpret figures from the primary literature
* Construct and support an analysis of patterns in datasets
* Work collaboratively to develop hypotheses, interpret results, and report on analyses
* Understand the biological impact of climatic variables on a single population, and how climate change affects species interactions in complex ways

**ASSESSABLE OUTCOMES:**

* Pre-lab reading and exploration of terms unfamiliar to the student
* **Interpretation of graph components and data patterns**
* New figures from a larger dataset (NPN) to test predictions
* Group presentations that include explanation of predictions, generation of a new figure from a large data set, and interpretation of the results

**SOURCES**:

* Inouye D.W., B. Barr, K.B. Armitage, and B.D. Inouye. 2000. Climate change is affecting altitudinal migrants and hibernating species. Proceedings of the National Academy of Sciences 97: 1630-1633
* End of Snow. <https://vimeo.com/184941494>
* The Snow Guardian <https://vimeo.com/182392548>
* National Phenology Network. <https://www.usanpn.org/usa-national-phenology-network>

**OVERVIEW OF THE ECOLOGICAL BACKGROUND**

In this adaptation, students start by exploring the figures from the original paper (Inouye et al. 2000). They use these figures as a basis for exploring the phenology of populations they choose that are recorded in the National Phenology Network (NPN) database. Students will explore whether the timing of natural history events have changed recently, and whether changes in timing are different for two species that interact within a community (consumer-resource, competition, mutualism).

**DATA**

We will use the original Inouye data as a jumping off point. Students explore the figures from the original paper, and then ask “What similar scenarios could I find?”

Data is stored at the USA National Phenology Network site <https://www.usanpn.org/usa-national-phenology-network>

Students will use the Data Visualization Tools to explore patterns of interest and detect possible mismatches in ecological interactions following the protocol in the lab assignment.

**STUDENT INSTRUCTIONS** (have been removed in favor of a pre-activity discussion – see PowerPoint Slides and Student Guide)

**Literature cited**

Inouye DW, B Barr, KB Armitage, and BD Inouye. 2010. Climate change is affecting altitudinal migrants and hibernating species. Proceedings of the National Academy of Sciences 97: 1630-1633.

**Notes to Faculty**

1. **Preparation before lab**

I modified this lab for a non-majors biology class that meets for 2.5 hours. I did not have students do any out of class work. I used this lab after covering chapters on community and ecosystem ecology. I also gave a short lecture on carbon and nitrogen cycles and human impacts on those cycles at the beginning of class.

1. **During lab time (2.5 hours)**
   1. Watch the video, The End of Snow (~20 minutes) or The Snow Guardian (5 mins).
      1. Discuss the general idea of what is being studied and why it matters to help prepare students for the article.
   2. Before beginning the activity
      1. Students read and discuss the paper and its findings to help them prepare to ask their own questions. Students need only get the general idea, patterns that are sometimes found, and the value of graphing temporal data.
      2. Guide a short discussion about the overall conclusions and predictions drawn from Inouye et al. (2000), using think-pair-share or similar approach. You may want to divide the paper up by section and have students use the jigsaw method to become familiar with one section and relate it back to their original group.
   3. Active learning (allow about 2 hours)

**Inouye Paper Guide** (about 1 hour) (interpreting plots):

* + 1. This is intended to get students familiar with regressions and how data can be visualized. I have used it as a standalone activity without the NPN exploration as a way to explore scientific publications.
    2. Students may need more detail about how data is presented in a graph. I include a graph from the paper in the PowerPoint to use as an example to discuss the parts of a graph.
    3. If time permits, consider having teams exchange their interpretations of the Inouye et al. (2000) figures (questions a-f). This can provide groups an opportunity to assess whether they are ready to move on to their own exploration.
    4. For non-majors, I recommend glancing over the answers for question 2, and having the group present their “story” to you before having them move on to the NPN site. This is a good check that they understand the core ideas of what they will be exploring in the next activity.

**NPN Guide** (about 1 hour; I hand out after they complete the paper guide and discuss it with me; exploring the new data)

* + 1. I recommend a list of pairs of species, such as monarchs and milkweed, hummingbirds and lilacs, so that there will be sufficient data available for a legitimate ecological interaction. I recommend going to the site, choosing the years of interest, then making a polygon around a reasonable region. Once you’ve done that when you choose species to look at, you will see how many observations are available for that species, and whether for your region of interest there will be good data. Using the entire database for a species is not good, because it waters down any patterns of change. Giving students 4-6 options for their groups to choose from allowed some freedom of exploration without the dead ends. I also recommend not choosing the phenophase, and maybe being vague with terms like “bee” rather than “bumblebee” if you want students to explore more and think more critically. This led to discussions with students about what phenophase would be most important, and what the interaction looks like between these species?
    2. The layout of NPN is quite good, but students may stumble into the “visualization” link without exploring the information available on the landing page. Direct them back to maximize the probability that they will know the potential of the dataset and visualization tools.
    3. The poster that is the last step of the lab is intended as a low-pressure, low-stakes way to get students to communicate science. I have students draw freehand on the board, with no specified format. For non-majors the intent is to present the data and conclusion(s) clearly and give them a tool to help explain their work and answer questions. I purposefully give them the very vague “poster” in the handout as a framework but try to not influence their efforts too much. The drawing they make can be very helpful in determining what they thought was important and can be used to test scientific competencies such as labeling of graphs and their interpretation. If time is too limiting, the poster drawn on the handout can serve as a record of their understanding, or it can be used as a guide for homework to make the poster.