Phenology and Climate: Lesson 3

Phenological Mismatch

Grade Level	9th – 12th Grade
Subject	Science
Course	Biology, Environmental Science

Essential Question

How does long-term temperature change affect bird migration? In what ways does a phenology mismatch affect bird carrying capacity?

Summary

In this final lesson of the series, students will explore the impacts of temperature change on bird migration and phenology. Through scaffolded analysis of graphical data and the use of an interactive digital model, students will develop an understanding of (1) how temperature influences bird migration over time, and (2) how long-term temperature changes can cause a mismatch in timing between resource availability and bird resource needs. From these activities they will draw conclusions about the biological significance of the data sets.

Snapshot

Engage

Students examine models of temperature change over time to draw conclusions.

Explore

Students compare the effect of temperature on insect and bird migration timing.

Explain

Students take notes about climate and make predictions about the consequences of changes in migration timing.

Extend

Students explore a model of phenological mismatch and discuss the nature of scientific data.

Evaluate

Students complete an exit ticket to explain how bird populations are affected by phenology mismatches.

Standards

ACT College and Career Readiness Standards - Science (6-12)

IOD502: Compare or combine data from a complex data presentation
IOD701: Compare or combine data from two or more complex data presentations
EMI502: Determine whether presented information, or new information, supports or contradicts a simple hypothesis or conclusion, and why

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

Oklahoma Academic Standards (Biology)

B.LS2.1 : Use mathematical and/or computational representations to support explanations of factors that affect carrying capacities of ecosystems at different scales.

Oklahoma Academic Standards (Biology)

EN.LS2.1 : Use mathematical and/or computational representations to support explanations of factors that affect carrying capacities of ecosystems at different scales.

Attachments

- Claim, Evidence, Reasoning—Phenology and Climate 3.docx
- How I Know It—Phenology and Climate 3.docx
- Lesson 3 Slides - Phenology and Climate.pptx
- Phenology Guide—Phenology and Climate 3.docx

Materials

- Lesson slides
- Paper (any variety, 1 per student for exit tickets)
- Poster paper (optional)
- Markers (optional)
- How I Know It handout (attached, 1 per student)
- Claim, Evidence, Reasoning handout (attached, 1 per student)

Engage

Show **slides 2-4** to introduce the title, objectives, and essential questions.

To begin the lesson direct students to the "Temperature" page of the Shiny app and display **slide 5**. You can use this slide to orient students to the features of the Temperature model. This page shows a map of the United States with points representing data collection points, and a grid to break the map into regions. Beneath the map is a temperature plot that shows data for a selected region and time period.

Give students time to explore the temperature change over time in various parts of the country. Under "Select Regions," students can select the "Click map to choose" option to look at data specifically for their state. As with previous activities, they should be looking for patterns and trends in the data. Though this is an informal exploration, consider having students note down their observations for discussion.

After a few minutes of exploration, display **slide 6** as a reference, and have students select "Show temperature anomalies" from the "Choose Temperature Plot" drop down menu. Explain the difference between temperature and temperature anomaly. They need to understand the concept of anomaly in order to interpret the model for this activity.

Teacher's Note: Temperature vs. Temperature Anomaly

Temperature is a straightforward measurement of the conditions at a given data collection site. Temperature anomaly is a measurement of how much the measured temperature differs from the average temperature at that data collection site over time. Positive values indicate how many degrees warmer the temperature is (in °C) compared to the average temperature, and negative values indicate how many degrees cooler the temperature is compared to the average.

For example, imagine a site has a 10-year average temperature of 25°C in April. A measured temperature of 26°C at that site in April would have an anomaly of +1°C, and a measured temperature of 24°C would have an anomaly of -1°C.

Have students share their observations and discuss the patterns and trends they identified as a group. Be sure to have them compare how trends in observed temperature data differ from the trends in anomaly data.

Explore

After the discussion, return to the Shiny app. This time the students will investigate the temperature variable for both the leaf hopper and the aerial insectivore data sets.

Teacher's Note: Aerial Insectivore Temperature Data

You will notice that the Aerial Insectivore Migration page does not include temperatures on it. For students to make conclusions about the effect of temperature on the birds, they will have to use the temperature data from the Leafhopper Migration page. Direct them to match the Year and Day of Year between the two pages to make accurate conclusions about how annual temperatures relate to bird migration.

Go to **slide 7** to show student how to match up parameters on the Aerial Insectivore and Leafhopper Migration tabs for comparison. Before exploring the models, distribute a copy of the **How I Know It** handout. Go to **slide 8** and present them with the following question: *In what ways, if any, are leafhoppers and migratory birds responding to temperature?* Give students a few minutes to discuss the question with their neighbors, having each pair or small group generate and write down one hypothesis for leafhoppers and one for migratory birds on their handout. You can choose to have groups share their hypotheses with the class or hold onto them for later discussion.

Go to **slide 9** to review how students should use the How I Know It strategy to collect evidence which supports or refutes their hypotheses as they explore the two models. The inferences and conclusions students are drawing from the data comprise “What I know”, and “How I know it” includes the specific evidence from the models that support those conclusions.

After students have had time to collect their data, come together as a class to discuss their results. Begin by asking how well they predicted the effects of temperature on the relationship between insects and migratory birds. To help facilitate a meaningful discussion of their findings, go to **slide 10** to present students with the provided guiding questions.

Go to **slide 11** to revisit the Driving Question Board. Have students record and share any new questions, and take a moment to answer any existing questions for which students have adequate information.

Explain

Continue to **slide 12**. Review the definition of climate with students. Two examples of climate zones are included for reference. Go to **slide 13** to show students a global climate classification map. The specific abbreviations don't matter. The point is for students to see the diverse climates found around the world.

Go to **slide 14** to clarify for students the difference between variability and change. The latter is relevant to the ongoing discussion about insect and bird migration. Continue to **slide 15** to provide examples of ways that organisms can be impacted by long-term temperature changes. **Slides 16-18** show range maps for the Scarlet Tanager: their current range, a projected range given a 1.5°C long-term increase in temperature, and a projected range given a 3°C long-term increase in temperature. Red represents places the birds would no longer live in (loss of range), while blue represents new places the birds would begin to live (range gained/range expansion).

Ask students to answer the two questions on **slide 19** to wrap up this section.

Teacher's Note: Guiding questions

- If a species can't respond quickly/match their timing to temperature change, how might that affect the species in the long-term? (Species that can't keep pace with temperature change/phenological shifts will be less successful at reproduction and may go extinct over time.)
- How would a population be affected by individual animals' abilities to respond to changes in temperature? (Animals who can keep pace with changes in seasonal timing will be more successful at reproducing, and those animals and their offspring with the ability will increase in the population over time.)

Extend

In Lesson 1, students learned about phenology as a concept, and now they will investigate what happens when the phenology of organisms become out of sync. Direct students to the "Phenology Mismatch" page of the Shiny app. Go to **slide 20** to orient them to how to interpret the graphs the model generates. Explain specifically that the temperature change bar can help us model the rate of temperature change (i.e., one degree increase every 10 years will lead to a warmer temperature after 80 years than a 0.5 degree change would). For additional model details, see the **Phenology Guide** handout.

Teacher's Note: Warmer or Cooler?

The temperature change slider bar allows students to model increasing and decreasing temperature in their exploration. The specific graphical results will differ depending on what temperature(s) they choose, but the theoretical impacts of the phenology mismatch remain the same.

Provide students with the **Claim, Evidence, Reasoning** handout and go to **slide 21**. Task students with answering the following questions:

- How does the rate of temperature change affect the results of the model?
- How does life history (i.e., caterpillar and bird sensitivity to temperature) affect the results of the model?

They should spend a few minutes exploring the model to come up with a claim that answers each question. Then, for their evidence they should describe the specific data which led them to make their claims. Finally, their reasoning should explain how the data support their claim, based on the concepts they've learned so far. Before continuing, have a few volunteers share out their CER answers.

Go to **slide 22** and review the information with students to formalize their understanding of what a phenology mismatch is. Next, **slides 23-24** show how we might visualize a mismatch. The graph on slide 23 is structured similarly to the Shiny graphs. The image on slide 24 shows how phenology would become mismatched if spring begins earlier in the year. The birds at the bottom of the figure show the spring migration, breeding season, and fall migration parts of the annual cycle for reference.

Teacher's Note: Nature of scientific data and models

Before concluding the lesson, it is worth pausing to have an informal discussion with students the strengths and weaknesses of the Shiny models and the nature of scientific data. Specifically, you should ask students to (1) evaluate which of the models they believe did or did not provide enough data/information to reliably demonstrate what happens in nature; and (2) discuss what they've learned about how scientists collect and use data and whether there are limits to our ability to use that data to make predictions. The following are some possible discussion questions:

- Which of the models do you believe is the best/worst and representing what actually happens in nature? Why? *(Possible student ideas: the leafhopper data set has lots of missing data; the phenology mismatch model doesn't use a real data set; the aerial insectivore migration and warbler arrival data sets aren't missing data/the data were collected by many people)*
- What can we infer about how scientists conduct their research from these data sets? *(Possible student ideas: scientists collaborate with each other, answering big questions requires more data than a single person/lab could collect on their own)*
- How much data is "enough" data to answer your questions?
- How might missing data affect your confidence in your results and conclusions?

Now, go to **slides 25-26** and revisit the Driving Question Board and list of Big Ideas one last time to answer any remaining questions and summarize their learning.

Evaluate

Before ending the lesson, have students complete an Exit Ticket to formatively assess their understanding of the content thus far. They should answering the following questions: *In what ways does a phenology mismatch affect bird carrying capacity?* and *What Shiny model do you have the most confidence in, and why?* They can use the evidence they collected during their previous exploration(s), to support their answer.

Teacher's Note: Additional Extension

If there is interest, students can return to the Aerial Insectivore Migration page of the Shiny App to investigate the effects of migration distance and body size. They should turn their attention to the data table included with the model. Using the table as a starting point, students will compare species based on their body sizes and migration distances.

Split the class into small groups. Assign half of the groups to investigate body size and the other half to investigate migration distance to answer the question *How does body size/migration distance affect migration timing?* If there are relevant Driving Question Board questions, they should investigate those at this point as well. Have students present their findings and discuss the results as a class.

If you want to formalize the activity beyond a group discussion, student groups could each create a Research Poster to present their information, include the following:

- Question and hypotheses
- Model Exploration (how and what data they explored)
- Results/Interpretation
- Conclusion (how their variable could contribute to phenological mismatch)

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Resources

- Bridge, E. (n.d.). Birds, Bugs, and Phenology. Shiny App. https://aeroecology.shinyapps.io/Birds_Bugs_and_Phenology/
- K20 Center. (n.d.). Bell ringers and exit tickets. Strategies. https://learn.k20center.ou.edu/strategy/125
- K20 Center. (n.d.). Claim, evidence, reasoning (CER). Strategies. https://learn.k20center.ou.edu/strategy/156
- K20 Center. (n.d.). How I know it. Strategies. https://learn.k20center.ou.edu/strategy/144
- K20 Center. (n.d.). Research Posters. Strategies. https://learn.k20center.ou.edu/strategy/49