PHENOLOGY LESSON TEACHER GUIDE

Age Group: Grades 6-12

Learning Objectives:

- To develop an understanding of the interconnectedness of the three trophic levels
- To make the connections between climate change and food abundances

Time Required: About 1 hour

Materials:

- Computers with internet capability
- Phenology worksheets
- Field Guides (optional)

Vocabulary:

Phenology - The study of the seasonal activity of organisms, especially in reference to climate.

Phenological mismatch - When the seasonal timing of different organisms that historically interacted (predator vs. prey, plant vs. pollinator, etc.) fails to coincide or overlap.

Background:

The climate is changing in different ways all over the world. In some regions that are getting warmer, spring may come earlier and summer may last longer than in the past. Many organisms have evolved very specific seasonal life history strategies, and vary in the degree to which they have adapted to recent changes in seasonality. This can lead to *phenological mismatch* if, for example, trees end up leafing out earlier because it is warmer, but insects fail to adjust to these changes. In that case, when the insects emerge, most leaves may no longer be as tender and palatable as they were when they first leafed out, meaning reduced food availability for the insects. Such mismatches could occur across multiple trophic levels, and in this exercise we will contemplate the potential impacts of matches or mismatches in the phenology of trees, insects, and birds.

Preparation:

- To help guide your students through the activity, identify in advance:
  - several butterfly species that are common in your area using e-Butterfly
  - several migratory bird species present in your area that have animated occurrence maps
  - the average green-up date for your local area based on the map here

Day of Activity:

Students can work through the exercise in pairs or small groups. Afterwards, have the class discuss their findings for the species they examined, as well as their answers about the potential impacts of phenological mismatch.

EXAMINING PHENOLOGY ACROSS TROPHIC LEVELS

Phenology is the study of seasonal life cycles of plants and animals. You may have observed an organism's *phenology* if you have paid attention to when the first daffodil emerged in spring, the first birds started nesting in your yard, or the first fireflies began lighting up the summer nights. As scientists, we are very interested in the natural calendar that is represented through phenological events, and in understanding how this timing might be affected by climate change or other factors. If one organism shifts its phenology, this may impact the other species that depend on it.

As an example, consider this simple food web:

birds eat caterpillars and butterflies which in turn feed on plants.

 [1]

 [2]

 [3]

Does this mean that these organisms will all have the same phenology? You will examine datasets that provide information about phenology in your area for plants, butterflies, and birds to find that out.

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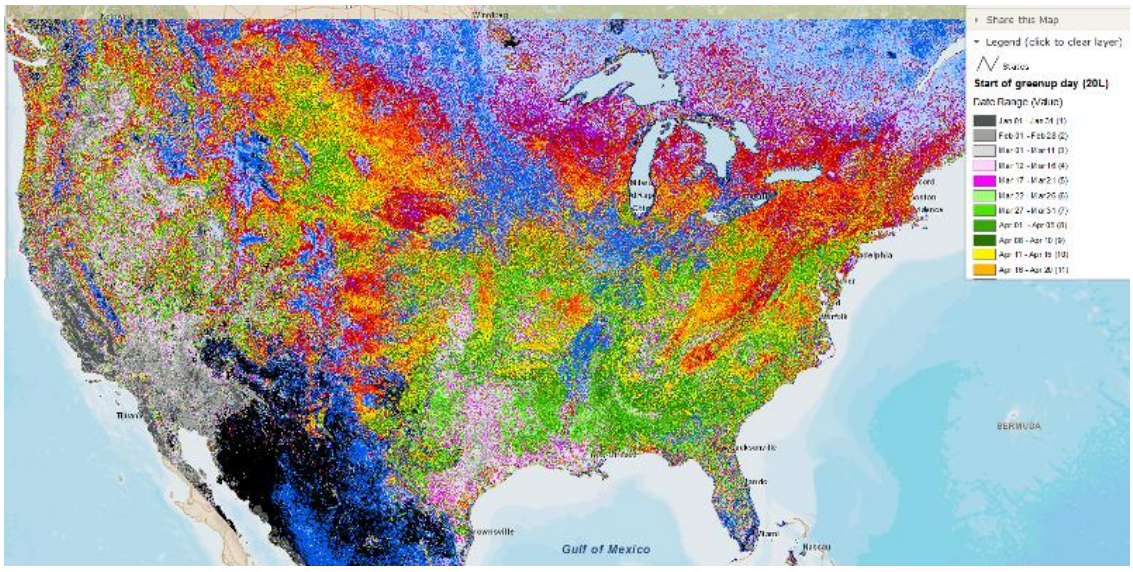
PLANTS

In order to get a grasp on the phenological events occurring in the plant world, we will use the U.S. Forest Change Assessment Viewer (http://forwarn.forestthreats.org/fcav2/) that allows us to see how the average "green-up" date—an estimate of the onset of spring—varies across the United States.

Go to the website linked above and follow these steps:

A. Under "Theme" in the top middle of the screen, select "MODIS Phenology Parameters Products."
B. In the "Map Layers" box, scroll down to the bottom and select "MODIS Phenological Parameters."
C. Click the very first box under "2000-2013 Medians," labeled "Start of greenup day (20L)." This shows the average day of the year over 2000-2013 that the landscape began to green up based on satellite observations.
D. Under "Map Tools", click on Legend and then on "TACs-NASA Products" to make that unused legend disappear. (You may need to do this in two places.) The legend should now displays how to interpret the different map colors with respect to time of year.

NOTE:
You may be able to skip steps A-D using this link: http://tinyurl.com/spring-greenup



Questions:
1. Describe how green-up date varies across North America.

2. What factors do you think are most important in explaining this variation? Are there any notable exceptions to the patterns you describe?

INSTRUCTIONS CONTINUED:

E. Now zoom in to the area where you live!
F. To get a better idea of where exactly to zoom in, scroll up to the top of the "Map Layers" box and select "Political Boundaries and Roads"
G. Then, select the check boxes beside "County Boundaries," "Cities," "Interstates", or anything else that might be useful in determining your location.

Questions:
3. What is the average green-up date where you live according to this map?

4. Why might there be areas around your location that have earlier or later green-up dates?

5. If winters and springs are growing gradually warmer, how would you expect this to affect plant phenology in terms of the green-up date?

INSECTS

We will examine butterfly phenology patterns in our state using the website e-Butterfly.org. Please go to:
http://www.e-butterfly.org/#/ebutterfly/observations/flighttimes

If you are already aware of some of the common butterfly species in your area, then great! Choose one of those from the drop-down "What species are you interested in" box. If not… then do a little research to see what butterflies are common in your state!

A. Once you have found a few species, go back to the webpage and select those butterflies from the drop-down "What species are you interested in" box.
B. Select your Province/State.
C. You can ignore the "Region or Country" and "Status" boxes.
D. Click "Generate."

Complete the table below for 3 species that occur in your state based on the "Flight times" graphs.

Species name	Peak flight date(s)

Questions:

6. Are the species you examined active at similar times of year?

7. If you were a bird that ate mostly butterflies, what time of year would have the best food supply based on the butterfly species you examined?

8. What time of year would have the best food supply if you were a bird that ate mostly caterpillars? Why?

B I R D S

We will also examine the timing of migration for bird species in North America. Looking at this will allow us to see the arrival and departure dates of the birds in your area.

Please go to: http://ebird.org/content/ebird/occurrence/

A. Through trial and error, find three migratory bird species that are present in your state throughout the late spring and summer but that are absent in the winter.
B. Using the animated occurrence maps for these species, determine the average arrival date of each species in your area based on the date that you first see an orange color on your area of the map. *Note: The date for each frame of the animation is provided in the lower left.*

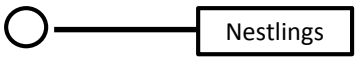
Species name	First arrival date

Questions:

9. After arriving on breeding grounds, a bird has to set up a territory, find a mate, build a nest, and lay and incubate eggs. This means that 4-5 weeks after arriving they might have some young nestlings to feed. Would any of the butterfly species you examined be at peak abundance when any of your bird species needed to feed its nestlings?

10. Many bird species depend more on caterpillars for feeding their nestlings than they do on the adult butterflies. Based on your answer to #7, would the caterpillars of any of the butterflies you examined be a useful resource for any of the bird species you examined?

11. Choose the closest match between a bird species and a caterpillar (i.e., the predicted caterpillar activity based on the butterfly flight chart).
    a. Draw a vertical dashed line at the average green-up date based on #1.
    b. Draw the flight chart for the butterfly species on the timeline below with a **solid line**.
    c. Draw the activity chart you predict for the caterpillar of this butterfly species using a *dashed line*. (It should have the same ups and downs, but will be shifted in time.)
    d. Make a circle for the bird's arrival date, and draw a line forward 4 weeks. At that point, draw a box that describes the period when a bird would be feeding nestlings, a period that might last ~3 weeks.



12. Imagine that next year the winter and spring are warmer than usual, and the plants and caterpillars shift their phenology accordingly. Many migratory birds spend the winter in Central or South America, however, and may not realize that spring has started earlier on their breeding grounds. If the birds migrate at their usual time, how might this "phenological mismatch" impact them?

Suggested Worksheet Answers

Questions:

1. Describe how green-up date varies across North America.

> *In general, green-up dates are later farther north and at higher elevations. You can see the long tongue of the Appalachians in the east, and the red and blue areas marking the Rocky Mountains in the west.*

2. What factors do you think are most important in explaining this variation? Are there any notable exceptions to the patterns you describe?

> *Green-up date clearly depends on temperature, being later where it is colder. Note an exception: the blue areas south in Illinois, Indiana, and Iowa indicate an even later green-up date than Michigan and Wisconsin. This probably reflects the timing of agricultural crops rather than the green-up date of natural vegetation.*

4. Why might there be areas around your location that have earlier or later green-up dates?

> *Local scale variation in green-up dates might be caused by local scale variation in temperature. For example, urban areas with more pavement and concrete may hold more heat and allow for an earlier green-up date. Different plant species also have different phenologies, so local scale variation in green-up may also reflect variation in the types of trees present in different locations.*

5. If winters and springs are growing gradually warmer, how would you expect this to affect plant phenology in terms of the green-up date?

> *Because green-up dates are determined in part by temperature, they have been coming earlier in many parts of the country due to climatic warming.*

6. Are the species you examined active at similar times of year?

> *This will depend on the species chosen, but time of year is highly variable across species.*

7. If you were a bird that ate mostly butterflies, what time of year would have the best food supply based on the butterfly species you examined?

> *This will depend on the species chosen, but imagine summing all 3 flight chart curves and finding the time of year in which that total is greatest.*

8. What time of year would have the best food supply if you were a bird that ate mostly caterpillars? Why?

Again, this will depend. But the important point is that students should recognize that if butterflies were abundant on May 15th, then presumably caterpillars were abundant 2-6 weeks earlier (depending on the species; ok to use 1 month as a rule of thumb for this exercise) prior to metamorphosis. A good place to review butterfly life cycles.

An exception would be butterfly species that overwinter as pupae (i.e., in their chrysalises), and then emerge as adults at the beginning of spring. In that case, you might expect to see caterpillars several weeks AFTER seeing the adults, after the adults have mated, laid eggs, the eggs have hatched, and the caterpillars have grown up a bit.

EXTENSION: Have students research their butterfly species to find out at what stage of the life cycle it overwinters. This will help them predict whether they would be more likely to find caterpillars before or after adults are observed.

9. After arriving on breeding grounds, a bird has to set up a territory, find a mate, build a nest, and lay and incubate eggs. This means that 4-5 weeks after arriving they might have some young nestlings to feed. Would any of the butterfly species you examined be at peak abundance when any of your bird species needed to feed its nestlings?

This will depend on the species chosen, but students should be comparing butterfly peak flight dates to the dates 1 month after their bird arrival dates.

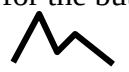
10. Many bird species depend more on caterpillars for feeding their nestlings than they do on the adult butterflies. Based on your answer to #7, would the caterpillars of any of the butterflies you examined be a useful resource for any of the bird species you examined?

This will depend on the species chosen, but students should be comparing dates 1 month prior to butterfly peak flight dates (or 1 month after if students have learned that their butterfly species overwinter as pupae) to the dates 1 month after their bird arrival dates.

11. Choose the closest match between a bird species and a caterpillar (i.e., the predicted caterpillar activity based on the butterfly flight chart).

a. Draw a vertical dashed line at the average green-up date based on #1.

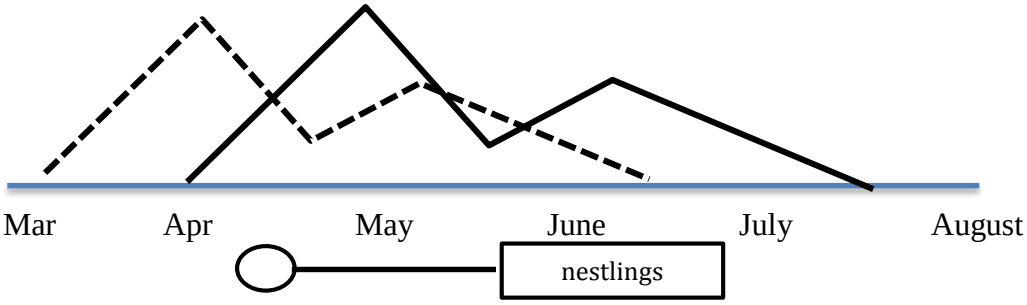
b. Draw the flight chart for the butterfly species on the timeline below with a **solid line**.



c. Draw the activity chart you predict for the caterpillar of this butterfly species using a *dashed line*. (It should have the same ups and downs, but will be shifted in time.)

d. Make a circle for the bird's arrival date, and draw a line forward 4 weeks. At that point, draw a box that describes the period when a bird would be feeding nestlings, a period that might last ~3 weeks.

Completed figure might look something like this:



12. Imagine that next year the winter and spring are warmer than usual, and the plants and caterpillars shift their phenology accordingly. Many migratory birds spend the winter in Central or South America, however, and may not realize that spring has started earlier on their breeding grounds. If the birds migrate at their usual time, how might this "phenological mismatch" impact them?

If birds arrive "late" on their breeding grounds, then by the time they have nestlings to feed, they may have already missed the peak period of resource availability. This could mean higher mortality of their young (and potentially of the adults as well), and if this happened for many consecutive years, it could lead to overall population declines.