Citizen Science and Long-Term Phenology Monitoring

Introduction

Phenology is nature's calendar—when daffodils bloom, when birds fly south for the winter, and when leaves turn color in the fall.

Phenology is defined as the "the study of the timing of the seasonal activity of plants and animals." Many phenological events are tied together by the timing of other biological events. For example, many insects time their breeding and offspring emergence to the time of leaf-out in plants so that their young have something to feed on. Many birds time their breeding and nesting so in time with the insects so that they can easily bring them back to feed their hatchlings. In fact, phenology affects nearly all aspects of the environment, including the diversity, abundance and distribution of organisms, food webs, ecosystem services, and the global nutrient and water cycles.

Phenology is primarily driven by three abiotic factors: sunlight, temperature, and precipitation (rainfall, snowfall, etc.). For example, Canada geese begin their migrations to their breeding grounds each spring. One of the main cues they use is the amount of available sunlight. In the spring, the amount of sunlight increases a little each day signaling that summer is right around the corner. Along with sunlight, birds also use the warming temperatures to determine the time of migration.

Phenological events are typically divided into **phenophases**, or "distinct events in the annual life cycle of a plant or animal in relation to changes in seasons and climate." In the tree leaves, these phenophases are very familiar: breaking leaf buds, leaves, increasing leaf size, colored leaves, falling leaves. Each of these phenophases typically take a certain amount of time and occur regularly each cycle. Some cycles, like fruit fly emergence, only take a few days, while others, like cicada emergence might take upwards of 10 years to complete.

Changes in phenological events and phenophase length are among the most sensitive biological responses to climate change. Across the world, many spring events are occurring earlier—and fall events are happening later—than they did in the past. However, not all regions and species are changing in the same direction or at the same rate. These differences in timing are starting to lead to mismatches in phenological timing, like pollinators emerging before the plant they need to pollinate have bloomed. These mismatches and changes could have a significant effect on ecosystems and landscapes over time, so predicting and quantifying these changes is very important, particularly as climate change accelerates.

Phenological cycles and phenophases have wide-ranging effects on humans and human systems. For many people, allergy season starts when particular flowers bloom or when leaves start falling. Phenology is also very important to farmers and gardeners, as they need to know when to plant to avoid frosts, and they need to know the timing of insect and plant development to decide when to apply pesticides and fertilizers. Many cultural events are also tied to phenological events, like the Cherry Blossoms Festival in Washington, DC or the variety of Harvest Festivals that take place around the world each year. In Virginia, one of the main drivers of fall tourism are leaf-peeping festivals, or events for tourists to see the fall color change in the Appalachians.

The fall color change primarily occurs in deciduous trees. **Deciduous** trees are trees that shed their leaves each year, usually during autumn. Leaves are shed when they are fully grown or mature. In the northern hemisphere, deciduous trees lose their leaves in preparation for cold and freezing temperatures during winter. During this time, nutrients and water are drawn from the tree into the roots for winter use. This process of storing nutrients and shedding leaves is called **abscission**.

Three main compounds control leaf coloration in deciduous trees. Throughout the spring and summer, **chlorophyll** a green pigment essential to the photosynthesis process, gives leaves their familiar green color. **Carotenoids**, water-soluble substances that produce yellow, orange, and brown colors, are also present throughout the growing season but masked by the bright colors of chlorophyll. As days get shorter, chlorophyll production slows down until it stops. The green color is no longer visible, and other pigments present (carotenoids) with the chlorophyll are then revealed. During autumn, bright light and excess plant sugars produce anthocyanins within leaf cells. **Anthocyanins** add color to red apples, blueberries, cherries, strawberries, and plums. They are also water-soluble and appear in the watery liquid of leaf cells.

Although always striking, the intensity and hue of the autumn leaf colors vary by year and region. Temperature, light, and water supply have an influence on the degree and the duration of fall color. Low temperatures above freezing will favor anthocyanin formation producing bright reds in maples. However, early frost will weaken the brilliant red color. Rainy and/or overcast days tend to increase the intensity of fall colors.

The fall color change is not only a perfect example of phenology, but offers a great opportunity to investigate ecosystem differences and species identification. For your laboratory report, you will investigate the phenology of a variety of tree species across two habitats to investigate the species and ecosystem differences in phenology of deciduous trees.

Observing the Plots

1. Your instructor will assign each group a tree to find and observe. The trees will be marked with tags indicating their number.

2. Record the tree ID # you have been assigned.

3. Record the date and time you begin observing.

4. Use the species guide to identify the species of the tree your group has been assigned. Check with your instructor then record on your observation sheet.

5. Describe the habitat around you tree. Is it in shade? By a road? Landscaped?

6. Find the phenophase list and descriptions for the species you are observing. Follow the directions for observing each phenophase and record your observations on your data sheet.

   A. Circle Y if the phenophase is occurring, Circle N if the phenophase is not occurring, Circle ? if it is not clear or you are unsure.

7. To measure the leaf buds, use the ruler and measure from the base of the bud to the tip (see image) record the bud length in the data sheet.

8. Repeat until your group has observed at least three trees.

Date:			
Time (start):			
Time (end):			
Tree ID #:			
Species:			
Tree Habitat:			
Leaf buds **Length:**	**Y N ?**	**Y N ?**	**Y N ?**
Breaking Leaf buds	**Y N ?**	**Y N ?**	**Y N ?**
Leaves	**Y N ?**	**Y N ?**	**Y N ?**
Increasing leaf size	**Y N ?**	**Y N ?**	**Y N ?**
Colored Leaves	**Y N ?**	**Y N ?**	**Y N ?**
Falling leaves	**Y N ?**	**Y N ?**	**Y N ?**
Flowers or Flower Buds	**Y N ?**	**Y N ?**	**Y N ?**
Open Flowers	**Y N ?**	**Y N ?**	**Y N ?**
Fruits	**Y N ?**	**Y N ?**	**Y N ?**
Ripe Fruits	**Y N ?**	**Y N ?**	**Y N ?**
Recent Fruit or Seed Drop	**Y N ?**	**Y N ?**	**Y N ?**

Data Analysis

The data table below displays data from Nature's Notebook for the yearly first leaf date (given as day of year) for *Acer rubrum* (red maple) for two regions, and data for the first leaf date gathered from herbarium specimen in the late 1800s.

SA = The South Atlantic Region (Our region)
    (average first yes day of year for DC, DE, FL, GA, MD, NC, SC, VA, and WV)
NE = The Northeast Region
    (average first yes day of year for CT, MA, ME, NH, NJ, NY, PA, RI, and VT)

Year	**SA**	**NE**
1890	111	115
1892	112	114
1896	116	120
1899	115	119
1909	112	116
1913	114	116
1917	119	124

Year	**SA**	**NE**
2009	113	121
2010	111	121
2011	115	142
2012	111	138
2013	130	155
2014	125	184
2015	142	176

1. Calculate the summary statistics (mean, range, median) and a scatter plot including linear trend lines and the equations for those lines. for each data set.

2. Use these figures and values to answer your homework questions.

Name: ____ G Number: ___________

Quiz for Experiments with the Phenology Lab

All questions are worth 0.5 points.

__________1. Which of the following is NOT a main non-biological factors that affects the timing of phenological events?

A. Precipitation
B. Soil pH
C. Sunlight
D. Temperature

__________2. Which of the following is an example of a phenological cycle?

A. Bullfrogs metamorphize from tadpoles to frogs.
B. Male deer grow antlers to begin the rut and breeding season
C. Canada geese migrate to Fairfax, VA in the spring to breed.
D. The leaves of a maple tree turn red in the fall.
E. All of these are examples of phenology.

__________3. What is abscission?

F. The midline of a leaf that all water and nutrients flow through.
G. The process of moving nutrients from leaves to roots in deciduous trees.
H. The process of leaves changing color in coniferous trees.
I. The process of cutting off the roots of a deciduous tree.
J. All of these are examples of abscission.

__________4. These water-soluble compounds produce a red-like color in leaves.

A. Chlorophylls
B. Nitrogenases
C. Carotenoids
D. Anthocyanins

Name: ____ G Number: _____________

Homework for Phenology and Citizen Science

Use the graphs you created of the yearly first color change to answer the following questions. Attach a copy of your graphs, labeled, and with linear trendlines.

1. Is the yearly first leaf date for *Acer Rubrum* changing over time? How do the summary statistics differ from the 1800s to the 2000s? What do those differences indicate?

2. Does the trend differ between the two regions in the 2000s? If yes, then describe the difference(s) you see and suggest a reason why.

3. Would you draw the same conclusions if you just looked at a period of just 2 years? Why is a data series over time important?

4. Predict what implications this trend might have for other species in the area.