The Climate Lab
Creating a phenology calendar

Introduction

In addition to the core Climate Lab measurements, some teachers have expressed an interest in expanding the kinds of data collected to include other phenology measurements. A good way to organize a plan for phenology measurements is to create a *phenology calendar.*

1. What is phenology? What is a phenology calendar?

"Phenology" is derived from the Greek word *phaino*, meaning to show or appear. Phenology refers to recurring plant and animal life cycle stages, such as leafing and flowering, maturation of agricultural plants, emergence of insects, and migration of birds. It is also the study of these recurring plant and animal life cycle stages, especially their timing and relationships with weather and climate.

Naturalists, farmers and gardeners, herbalists and hunters have always been attuned to these seasonal changes. In some European countries, the national weather service has citizens reporting phenological data about common species, and these data are used in advising farmers about when to plant and harvest. Records of these data have also provided important evidence about changes in climate in New England and around the world.

(For one example, see this article about the records kept at the Mohonk Mountain House http://www.nytimes.com/2008/09/16/science/earth/16moho.html?pagewanted=all)

A p*henology calendar* is simply a record of phenological observations, organized by months and days. Some people just keep a diary or journal, noting their observations and the date. Others keep their observations in tables or charts as they accumulate data over several years. Some also keep notes on weather or other phenomena at the same time.

2. Why a phenology calendar?

Phenology records are interesting in and of themselves, providing a sense of history in the observer's location. They provide an interesting and accessible way to look with more care and insight at the natural phenomena around us.

They also can be of great value for more formal scientific investigations based on questions that the observer may not have been asking when she began her recording. For example, phenological measurements have helped scientists understand many aspects of plants' and animals' biology, physiology, and life histories. In recent years, phenological data have been increasingly important in relation to climate change, as scientists try to understand how ecological communities are changing in response to a warming world.

3. Using the phenology calendar to stimulate student investigations

While the phenology calendar is a good way to monitor long-term changes on the landscape, it also can open the door to a wide range of investigations that students can design and carry out for themselves. Such investigations can be used as science fair projects, as the material for independent projects, to deepen their understanding of many different science topics and practices, to encourage their interest and their confidence in science, and to engage their school learning, and out of school science, with issues of community interest.

4. Join the phenology movement!

There is a growing range of local, regional, and national citizen science projects founded on phenological study, involving people of all ages and walks of life — in this country and around the world. The data your students collect for their calendar, as well as any other projects they develop over the years, can make a valuable contribution to the many studies that are contributing to a better understanding of our changing world. Moreover, the data they collect can be made more meaningful, interesting, and fun if they are added to, and compared with, data collected by other researchers. Connecting to these networks can give you new ideas for investigations to undertake in your study area. In what follows, we'll include links to some of these networks, and they will connect you further. The possibilities will keep unfolding!

For a "blogroll" of some phenology blogs, see https://www.usanpn.org/news/phenology-blogs.

Getting started

As organisms live through their year, key parts of their life histories are tied in some way to the seasons. Day length can trigger seed germination, or cause birds to begin molting or prepare to migrate. Flowering in some plants can be triggered by temperature (sometimes in the form of "degree days"). Some species coordinate their reproductive activity to ensure that there is maximum food available, or particular prey species available.

Phenology studies specific seasonal events in an organism's life. Thus, one can measure the onset of reproductive activity in a species — the opening of flowers, in a plant, or the calls of frogs. The opening of leaves on trees is another feature that can be studied, as is leaf-fall in the autumn. The emergence of some insects can be observed (e.g. Dragonflies), as can other insect behaviors, such as the first appearance of certain caterpillars. Some of these phenomena are easier to observe than others, so choosing the species and the phenophase(s) to observe is at the foundation of a good phenology program.

But just as important is to decide on some research questions which the data will help you answer. They can start out being quite simple — "When do Red-winged Blackbirds return to the wetland near our school?" and "Do blackbirds come back earlier at the school than at the Boston Nature Center 25 miles north of here?"

Then you can get more sophisticated: "Is there a relationship between the first appearance of certain species and the average temperatures in the prior 3 months?" or "What is the order in which wildflower species bloom on our transects?" Such questions can in turn lead to more!

Getting started

Here are 6 basic steps for planning out your phenology calendar.

1. Choose one or more species to study

What's interesting about them? For example, they may be very common, or very important, or very visible, or very exciting or valued by the community.

For the Climate Lab, we recommend that you choose several species to observe, and that you include in your program a few species that all Climate Lab projects will be observing.

A. Species for all Climate Lab schools to use

These have been chosen because they are widespread and easily recognizable. If you have a favorite to suggest, feel free to share it with the Climate Lab network, and we can discuss it and decide whether to incorporate it into the "shared species" group.

Red maple	First caterpillar	American Robin
Dandelion	Spring peeper	Red-winged Blackbird

B. Widespread species that many places may use

Canada mayflower	Poison ivy	Osprey
Great Egret	Black cherry	

C. Choose your own

You and your students should identify a few species that you find interesting in some way (e.g. they're common, or puzzling, or fun, or attractive), to add to the list of species to track. Think about including species from different taxonomic groups — birds, plants, insects, amphibians, mammals, or fish.

For more ideas, you might want to visit the USA National Phenology Network's website http://usanpn.org, where many different citizen science groups are reporting their information.

It may be also that there are species being tracked in your state

2. What will you record?

For each species, identify the phenophase(s) that you will record for it. Note that many of these may have more than one cause (for example, the expansion or contraction of a species may be caused primarily by a change in land-use). If your primary interest is in climate change and its effects upon the landscape, you will want to correlate the biological observations with weather and climate data (collected by yourself or by some agency) — but climate effects may or may not be part of the mechanism of the change you see! For details about phenophases, see the Briefs on phenology observations that accompany this guide.

Here are the suggested phenophases for the species listed above:

A. Species for all Climate Lab schools to use

Red maple	flowering begins
Dandelion	first flower
Spring peeper	first calls, last calls
Red-winged Blackbird	first arriving males
First caterpillar	
American Robin	first appearance

B. Widespread species that many places may use

Canada mayflower	leaf-out
Canada mayflower	flowering
Poison ivy	leaf-out
Osprey	first sighting
Great Egret	first sighting
Black cherry	leaf-out
Black cherry	flowering

Note: In addition to phenophases, you may want to record other kinds of data. Two that are particularly interesting and useful are:

Presence/absence of interesting species or phenomena. This is a way to explore changes in which species are part of your landscape. This includes such phenomena as the appearance of new species not recorded before in your area (perhaps moving in from the north or south); the arrival and location of problem species (invasives, pest species, and the like), or simply the species of a certain taxon present at the same time each year (such as the long-running Christmas Bird Count). In addition, many areas now hold "biodiversity blitzes" (the name varies), in which teams of experts and amateurs seek to catalogue all the species in a specific location that they can find within a set time period (often 24 hours) (see http://www.nationalgeographic.com/explorers/projects/bioblitz/). Such surveys have produced surprising results [for just one example, see http://www.dailyherald.com/article/20150717/submitted/150719128/]. Presence/absence data of many kinds are being tracked around the world, and there is always a need for more people to join in!

Changes in the abundance of species, such as rare species, invasive, species, well-known or beloved species, or just unexpected increases or decreases in the composition of the flora and fauna of your area. Here again, many people are watching these phenomena, but there are a lot of species and a lot of landscape, so there's plenty of room for you to carve out an interesting and valuable

project. Check out the website of the Gulf of Maine Research Institute's Vital Signs program, which focuses on invasive species monitoring http://vitalsignsme.org.

3. Does your question involve taking more than one measurement?

Some protocols, like the Climate Lab, ask you to collect a set of data (vegetation measurements and weather) to adequately capture the phenomena of interest. The data you take should be linked to your research questions.

Your own phenology research questions may be more specific, or fewer, or less complex — for example, you might have a question like "When do we first detect the first spring appearance of these species?" In this case, it's not hard to specify the data you'll need to take. A broader question, such as, "How are invasive species responding to climate change in our area?" is much more ambitious, and will need to be broken down into several specific parts, each of which will dictate the data to be collected.

4. Do you know how to do it?

For your data to have value, to yourself and others, you need to have a reliable way to be accurate. So once you have decided what data you will take each year, you need to have clear instructions for how to take the data (make the measurement or observation). These should be written down (photos and video can help, but do not substitute for a step-by-step description!!!), so that anyone who joins your project can do the work reliably. It also means that when you report your results to anyone, you can describe exactly how you got the results, and this will help others know how reliable the information is, and how your data might be replicated in order to verify or strengthen the discoveries you are reporting.

If you decide to take data that will contribute to an already-existing project or study (like Budburst budburst.org, or eBird ebird.org), these descriptions will be provided for you, and you can use such descriptions as models for your own research protocols.

5. Who will take the data? Where will you keep them?'

These are questions that any research project needs to answer. If there's a lot of data to collect, dividing up the work is a way to make sure you get it done in time, without anyone's being too overburdened by it. If your calendar includes several species, or several kinds of observations, you may want to make sure that everyone in your class knows how to take all the different measurements, but then allow people to specialize, focusing on one organism, or location, or other particular topic of interest.

Once you divide the work up, though, you need to build in ways to make sure that everyone can read the data, and that copies are made of the data sheets, and data entered into spreadsheets for analysis. The date, location, measurement, and person measuring should be recorded, so that each data point's history is clear. In the spreadsheet and on data sheets, leave space for "observer notes" in case the people out in the field see things of interest that might be good to record. Also valuable to record as the data are taken and entered are any questions or ideas about the observations, related to the research project, which might open new investigations down the road.

6. Who will you tell about your findings?

You should make a habit of writing up and presenting your findings for each year. Of course, you are doing this project for your own interest and learning, but your results may well be of interest to others — other schools in the Climate Lab project (through the Climate Lab website), to community groups (like the local conservation commission, garden club, nature center, and more). Writing up the data helps you think about what you've done, asking yourselves "How does this help

me answer our research question? What new questions does this year's work suggest? What else should we learn to help us make sense of our data? Who could we talk to, to help us get ideas and see what our data mean?

You may also want to submit your data to the USA National Phenology Network, through Nature's Notebook. This website is becoming an important place for anyone interested in phenology, and you can both learn a lot from it, and help others learn, by contributing your data. See usanpn.org for more information about how to join Nature's Notebook.

Working with your data.

Taking data is fun — people generally enjoy working outside together (depending on the weather, of course!), and phenology data collection feels a little bit like a treasure hunt. But collecting the data is just one part of the larger whole. After all, observations become "data" because they are collected to answer a question. The question you're seeking to answer dictates the kind of information you collect, and how, when, and where you collect it — but you have to use it then to seek understanding. Here are a few tips on getting into your data.

• Don't wait too long to do some analysis. Start by examining *data quality*. As soon as you have some of the data you plan to collect, you should make sure that the data are being collected accurately, and recorded legibly. Do you know where and when the data were collected? Do the measurements seem reasonable (that is, to be roughly what you expect? For example, you expect leave-length of a particular species to vary somewhat, but if you see a leaf length that seems dramatically larger than any other in the set, it's worth checking to make sure there wasn't an error in the measurement or recording of the data. Keeping careful track of where the data are recorded helps sort out unusual readings from impossible ones.

> Unusual things do happen — once, a Climate Lab student took data on a site measured the previous year. She measured tree heights, and later when we were reviewing the data, we saw that one tree had shrunk dramatically. Was that a mistake in the measurement? Or did she measure the wrong tree? Because the location was clearly identified, we went back to that spot, and saw that the tree had suffered severe damage from snow the previous winter, and the top had broken off — so the "short" measurement was accurate. Reviewing the data as it was coming in alerted us to a possible problem. The Climate Lab protocol enabled us to check out the surprising data point, and confirm that the "backward growth" was for real!

• Do the data begin to answer your research questions? Of course, one year's data won't answer a question that may take several years to really grapple with. The whole point of long-term studies is to see things that take longer than a year to unfold. But it helps you to think deeply about your project to look at the data you've collected, and ask yourself: Is there anything surprising here? Are there things I don't quite understand?

• Look at it more than one way — tables, graphs, charts, words. Your data will first probably take the form of lists, but it's very helpful to turn it into a narrative, which starts with the design of the project (what you are doing, why you are doing it, which species you've chosen, and the methods briefly described), and then reports on what you've found this year, and compares it to previous years' data (if any) and also similar data collected by others. End with questions or conjectures that you have for the next round of work. It can be surprisingly hard to turn "data" into "findings" in this way. It can help to identify an audience that you are writing for — other schools, a citizen-science group, the town conservation commission, etc.

Graphing data, or even arranging in a chart, can be revealing as well, and it's worth looking at other people's data displays (see the National Phenology Network and eBird for examples) to get ideas for ways to "transform" your data. Once you have a few years' data collected, an animation or slide show might be both fun and instructive.

Some people make "phenology wheels" to track a set of species around the year: http://earthzine.org/2011/02/14/phenology-wheels-earth-observation-where-you-live/

But you can use an actual calendar format (http://www.northraccoon.org/North_Raccoon/Calendar_files/2014%20Phenology%20Calendar_007.jpg), or other "timeline" form, to display your observations, which can help you see relationships and differences that may stimulate your thinking.

Beyond the calendar

A phenology calendar can be a lens and a doorway into further learning and research. Here are some suggestions for areas you might want to open up.

1. Other phenology questions. Once you have gotten your phenology project going, you might decide to add additional organisms to the project, or additional phenophases of the same organisms. You can search for reports on other research being done on the phenology of your species.

2. Relating to other data sets. You already know that phenology is an interest shared by thousands across the country and around the world. You can use websites like usanpn.org or others to look at data collected elsewhere — in other timezones, other latitudes, other continents — about your species, or others, and compare the trends they're seeing with those that you and other Climate Lab participants are seeing.

3. Going deeper into the biology or ecology of the species you're studying. Pollination, dispersal, habitat….

4. Branching out. You may find that as you get deeper into the responses of animals and plants to climate change that you become interested in other aspects of climate change. For example, you might want to find out more about the issue as a global phenomenon, learning about sea-level rise, or ocean acidification, or the loss of ice from ice-caps and glaciers. Or you might be interested in what the evidence is for climate change in the past of earth's history. You might consider going in another direction — telling others about how climate change is affecting your area, and encouraging them or helping them to find out more. You might want to find out about ways that people are trying to slow climate change down, or adapt to its effects in your area