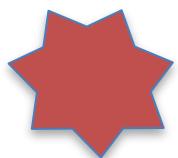
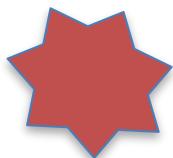


CATERPILLARS COUNT!



Tracking the Phenology of Bird Food

<http://caterpillarscount.unc.edu>



BACKGROUND



BACKGROUND

WHY DO BIRDS MIGRATE?

Of the 650 bird species that breed in North America, some live in the same area year-round but the majority are migratory. These species migrate northward to take advantage of the wide range of insects, fruits and seeds that become available in the spring and summer. These resources are a critical ingredient for successfully raising hungry nestlings.

HOW DO BIRDS KNOW WHEN TO MIGRATE?

Like many things in life, timing is everything. If birds return too early, they may be at risk from severe winter weather, and little food may be available. Come back too late and they may have to settle for second class breeding territories, and the peak of insect biomass that they were counting on to raise hungry nestlings may have passed. While migration is not completely understood, it is known that there are certain “triggers” that tell birds when to migrate. These triggers can range from length of day, to change in temperature, to internal biological rhythms.

WHY DOES IT MATTER?

Climate change is affecting the timing of spring leaf out, the timing of insect activity, and the timing of avian migration and breeding. The question is: ***Are the plants, insects and birds all responding to the same degree?*** If insects or birds are not keeping up with phenological shifts of the other types of organisms that they depend on, then further climate change may have negative consequences for their populations.

If you would like to learn more about bird migration, please visit:
<http://www.birds.cornell.edu/AllAboutBirds/studying/migration/>

HOW CAN WE HELP?

MONITORING BIRD FOOD

Caterpillars are one of the most important sources of food for many migratory birds, and provide a tasty snack for growing nestlings. Are caterpillars more abundant on certain tree species over others? Does the peak abundance of caterpillars vary from year to year, and has it been changing with climate? Here's where you come in! You will help to collect information on the abundance and phenology of caterpillars and other insects so that researchers can ultimately evaluate any trends and relate them to bird population trends in those same areas.



FREQUENCY

Understanding the phenology of insect resources for birds requires conducting foliage surveys throughout the season. If possible, conduct a set of visual foliage surveys *once every 7-14 days* from the beginning of the season (when spring leaves first start flushing out) until the end of July. This will allow us to estimate the timing of peak resources. But even if you are not able to conduct repeat surveys, your data can still help answer important questions about which tree species support the most caterpillars and other arthropods.

INSTRUCTIONS



SITE SET-UP

ESTABLISHING THE MONITORING AREA

Choose an area that contains representative vegetation of the common shrubs and trees at your location. This area will typically be less than 100 x 100 yards, but large enough to encompass 4 to 8 survey circles that are ideally spaced 25 yards apart. If working with a small area, it is okay for the circles to be close together. These circles may be arrayed in a loose grid, a line, or some combination depending on the configuration of vegetation at the site. Each of the 4 circles should be centered on a representative bush or small tree that has leaves available for inspection. *To increase comparability between sites, we WILL NOT be sampling grasses and herbaceous plants.*

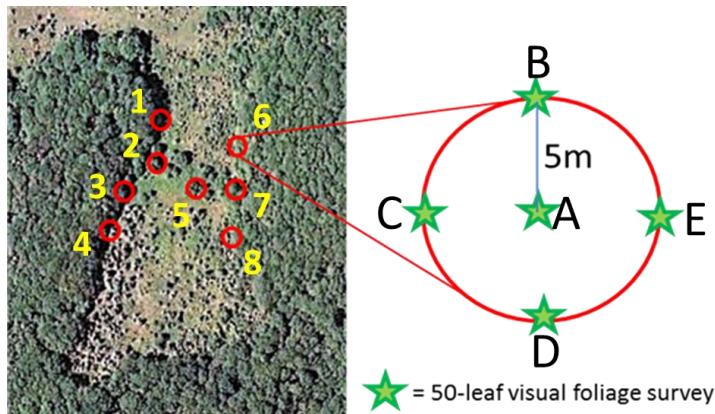


Figure 1. Example of a site with 8 survey circles distributed across it. Each circle consists of 5 survey locations.

SELECT THE TREES WITHIN THE MONITORING AREA

Each circle will consist of 5 survey locations labeled A (in the center), and B-E as illustrated above. While the center point for a survey circle may be chosen based on subjective criteria (seems like a good general location for surveys, vegetation is representative, etc), survey locations B-E should be located in each of the 4 cardinal directions. In order to select these survey points, abide by the following steps:

- 1. Select the center point:** When selecting the center point, A, it is important to choose a tree that can be easily surveyed. You are in search of a tree that has at least 50 leaves that measure 5cm (~2in.) in length. Therefore, choose a tree that has a relatively high abundance of leaves. If finding 50 leaves to survey proves to be a challenge then you are probably better off choosing another tree. It is also important that the leaves are at a height that is easily accessible. Using a ladder is not a practical way to gather data, so these should be leaves that you can see at eye-level.

2. Find trees B-E: Once you have selected A, walk 5 yards (approximately 6-7 steps) in one of the cardinal directions. It is best to do this with a compass. The first plant with 50 leaves that are at least 5cm (~2in.) in length is the plant that you should survey. If there is not a plant directly in front of you, then you can use a plant that sits within 10ft. of your transect line. If there is no suitable vegetation at 5 yards and within 10 feet, continue walking along your transect line away from the center point until you find a tree with 50 leaves. Repeat this process until you have picked out trees B-E.

3. Record survey tree species: Once you have selected your survey branches, record the tree species they are on, and enter this info on the website.

- Click on the *Administration* tab, and log in.
- Click the Plant icon on the right side for the site you'd like to edit.
- Click the edit button at right to enter the tree species for each survey location.

4. Print and hang QR codes: Once you have entered tree species information, you may generate, print, and hang QR codes for each survey branch on the website.

- Click on the *Administration* tab, and log in.
- Click *Generate QR Code* from the left hand menu, and then *Create QR Code* for the relevant site.
- This page may be printed directly to your printer.
- Laminate or print on rite-in-the-rain paper before hanging.

If you are not permitted to hang QR codes at your site, you may use some more discreet means of identifying survey branches, but make sure that participants will be able to easily find them. These branches will ideally get surveyed each year.



This tree has been labeled with a QR code generated on the project website.

COMPLETING THE SURVEY

EQUIPMENT NEEDED

- Smartphone / iPad with Caterpillars Count! app
- Leaf photo scale sheet

OR

- Clipboard
- Visual leaf survey datasheet
- Digital Camera
- Post-it notes
- Leaf photo scale sheet
- Pen/Pencil

OPTIONAL: Beat sheet (see assembly instructions in the back), and stick

SURVEY TYPE

You may choose to conduct either of two types of surveys of foliage arthropods: a visual survey, or a beat sheet survey. In either case, the goal is to quantify the number of arthropods observed over some known area of leaves searched. A ***beat sheet survey*** is a little bit quicker, and more appropriate for participants with short attention spans (i.e. kids!), and involves holding a white sheet under a branch and then whacking that branch with a stick. You can then count all of the bugs that have fallen off the branch onto your sheet. A ***visual survey*** takes slightly more time and patience, and involves carefully inspecting by hand a set of 50 leaves on a branch. To conduct this type of survey, all you need is a datasheet or smartphone to record your data.

Whichever type of survey you choose to use, we ask that you be consistent and conduct all surveys with the same method whenever possible.

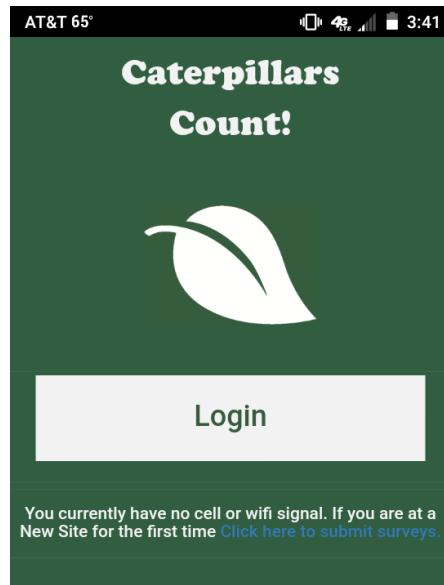
General Tips

- Arthropod length is from the **head to the abdomen**—don't include leg or antennae length.
- We only care about arthropods **≥2 mm long**. Don't spend time sweating the small stuff!
- It's important to record each arthropod. If you can't identify one, enter it as '**Unidentified**'.
- Taking photos of the arthropods you find within the app is optional, but **we strongly encourage photos of caterpillars!**
- For our purposes, each individual leaflet within a compound leaf (e.g. hickory, buckeye, ash, etc.) will be counted as one leaf.
- The leaves you survey should be no more than 6.6 ft. off of the ground, although the plant you survey may be much taller.
- If you realize that the plant you are surveying has a dwindling leaf-supply, you can also survey plants *of the same plant species* in the general vicinity.

SUBMITTING DATA WITH THE MOBILE APP

Getting Started

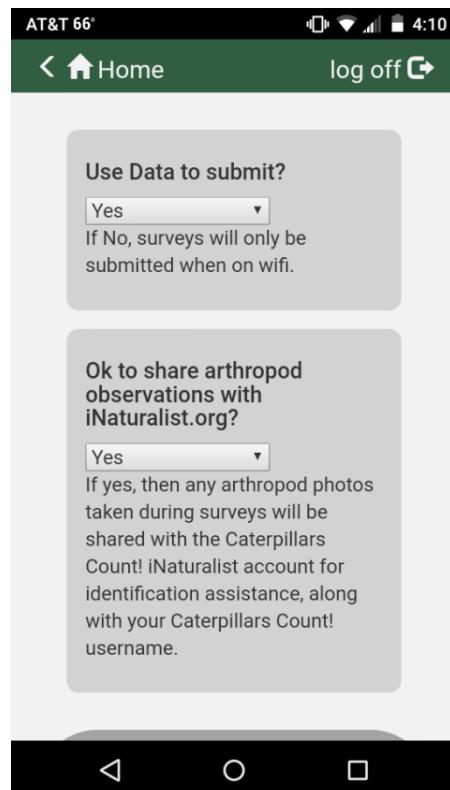
To get started with Caterpillars Count, download the app from either the Google Play or Apple App Store and open it. If you have never used the app before, you can create an account by tapping the “Register” button on the start screen. You’ll then need to confirm a registration email sent to that account. Once you’ve registered, you’ll be taken back to the start screen. Tap the “Login” button to enter your information. Once you’ve provided a username and password, they will be stored on your device. From that point on, you can open the app and get started without having to enter your user information. If you don’t want to be automatically logged in, you can change the “Remember Me” option on the Login page.



Settings

The first time you use the app, you will want to configure two settings, which are available by tapping the gear in the top right after logging in. First, if you would like to submit surveys using cellular data (assuming you have a cellular data plan AND that the survey location has cell service), set “Use Data to submit?” to YES. The default is that the app will only be able to submit when connected to WiFi, which may be once you’re back at home or in the classroom (see *Pending Surveys* below).

Second, although we only expect participants to identify arthropods to Order, expert identification of your observations to species may be possible if you elect to share photos taken during surveys with the citizen science website iNaturalist.org (select YES for this option). Arthropod photos from your surveys will automatically get shared with the Caterpillars Count! iNaturalist page (www.inaturalist.org/observations/caterpillarscount), and you will be able to see experts weigh in on what you've seen! Note that your Caterpillars Count! username (i.e., the part of your registered email address before the @) will appear in the notes of the observation as shown on the next page. Unfortunately, we are not able to link to personal iNaturalist accounts at this time.

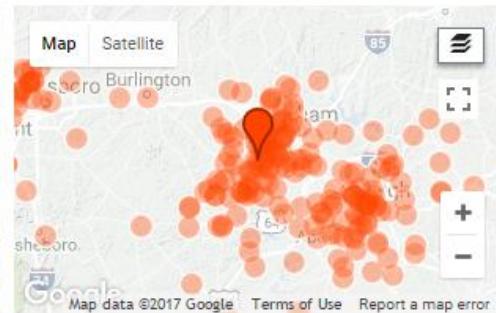


[« caterpillarscount's observations](#)

Spiders (Order Araneae) · Observed by caterpillarscount · February 17, 2017



Photo © caterpillarscount, some rights reserved



Location: Test (Google, OSM) [Details](#)

Added: Feb. 17, 2017 16:21:33 -0500

App: Caterpillars Count - dev

Average length (mm): 7

temperature_range: 60-69

Site Name: Test(NA)

circle_number: 3

survey_number: A

Plant species: Camellia

leaf-count: 50

herbivory: 1

Arthropod Count: 1

user: hurlbert

iNaturalist observation page showing user id

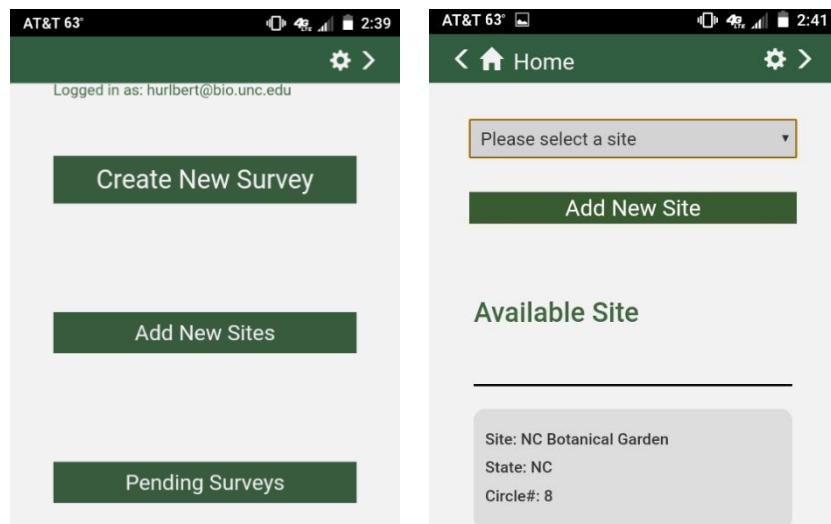
App Home Page

Once you login, you'll be taken to the app's homepage. You'll see three buttons labeled "Create New Survey," "Add New Sites", and "Pending Surveys."

Add New Site

The "Add New Sites" button takes you to a page that displays all sites to which you currently have access. If you've never used the app before, the Available Sites page will be empty. Add a new site by selecting it from the menu and clicking "Add New Site". You will then be prompted for the site password, which you should have obtained from the local site coordinator.

If you do not know the site password, you can still create surveys which will get stored as Pending Surveys, but those surveys cannot be submitted until you have successfully added the site with the correct site password. **Add New Sites only works with cell or WiFi service.**



Conducting a Survey

The “Create New Survey” button is where the action happens. This is where you’ll enter your observations of foliage arthropods, but also the information about the temperature, time, date, location, plant species, leaf count, and herbivory level you observe. A typical survey would be completed as follows:

- 1) **TIME** and **DATE** will autofill with the current time and date, and unless you are entering data that was collected on some other occasion, you will not need to adjust them.
- 2) **TEMPERATURE**. Enter a Temperature range that describes the current temperature.
- 3) **SITE / CIRCLE / SURVEY or QR CODE**. If the site you are surveying has QR Code tags hanging on the survey branches, then you can tap the "Scan QR Code" button, scan the code, and the SITE, CIRCLE, and SURVEY fields should get filled automatically. If there is no QR Code, you will specify these fields manually based on the information on the branch tag. Note that surveys are lettered A-E, and occur in groups of five called "Circles", which are labeled numerically.
- 4) **SURVEY TYPE**. You may choose to do a **Visual Survey** (in which you inspect a set of 50 leaves and associated petioles and twigs), or a **Beat Sheet Survey** (which requires that you beat a branch over a "beat sheet" [see assembly instructions]).
- 5) **NOTES**. This is a space to enter notes about potentially relevant observations that might apply to the entire survey as a whole. For example, perhaps it just rained and all of the leaves on the survey tree are very wet. Or perhaps the branch was bent or disturbed since the last time it was surveyed. You can describe these things here.
- 6) **ARTHROPOD OBSERVATIONS**. For each new arthropod Order you observe, click on the "ADD" button to the left, and select the arthropod you observed from the dropdown menu. If the arthropod type is not listed, you may select "Other" and describe in the Arthropod Notes field what it was. If you are not sure what type of arthropod you observed, you may select "Unidentified", and can describe any relevant aspects of its appearance in the Notes. Also record the length of the arthropod(s) you observed in millimeters, and the number of arthropods observed of this type and size. You may optionally take a photo of the arthropod. Click "Save" to add this observation record to your survey, and you will see a record of this

The screenshot shows the mobile application's survey creation screen. At the top, it displays 'Carrier' and '10:04 AM'. Below that is a header with a back arrow, a home icon, 'Go back', and a gear icon. The main area is divided into sections: 'Temp.' (with a placeholder box), 'Time' (set to '10:04 AM'), and 'Date' (set to 'Nov 6, 2016'). A large green button labeled 'Scan QR Code' is present. The next section, 'Site Information', contains dropdown menus for 'Site' (placeholder 'Please select a site'), 'Survey Type' (placeholder 'Please select a survey type'), 'Circle' (placeholder 'Please select a circle'), 'Survey' (placeholder 'Please select a survey'), and 'Notes' (placeholder 'Please select a notes').



observation displayed in the ARTHROPOD ORDER INFO section. For every new arthropod you see within this survey, fill out a new record by clicking "ADD".

Note that if you conducted a survey and saw 5 ants, four of which were 3 mm and one of which was 10 mm, and 1 caterpillar of 35 mm, that would require 3 separate records to fill out: 1 for the ants of size 3 mm, 1 for the ant of size 10 mm, and 1 for the caterpillar (see figure).

If you conducted a survey and saw NO ARTHROPODS, then you need not fill out this section and can move on to #7.

- 7) PLANT SPECIES. If your survey has a QR code then this may have filled in automatically. If not, enter the plant species that you surveyed if you know it, or if it is written on the survey tag hanging from the branch. If you do not know, you can write "Unknown".
- 8) LEAF COUNT. If you conduct a Visual Survey, this count will be 50 and cannot be edited. If you conduct a Beat Sheet Survey, please estimate the number of leaves that were hanging directly over the beat sheet when you beat the branch.
- 9) HERBIVORY. Give your 50-leaf sample an herbivory score based on how much leaf damage there is. Herbivory scores are as follows: 0 - none, 1 - trace (<5%), 2 - light (5-10%), 3 - moderate (10-25%), 4 - heavy (>25%). If you summed all of the observed leaf holes together over a 50-leaf survey and were able to cover 5 average leaves, that would be 10%. If leaf holes only sum to about 2 average leaves worth, that would be 4%, etc.
- 10) LEAF PHOTO. Please take a photo of an average sized leaf from the sample you just surveyed. This works best if you can rest it flat on a white sheet of paper so that there will be strong contrast between the leaf and its background, and it is helpful to have an object of known size in the photo for scale. We have a Leaf Photo Scale Sheet available on our website that can be printed out for this purpose. Please ensure the photo is taken from directly above the leaf at a 90 degree angle. Otherwise the image will be distorted and yield a less accurate estimate of leaf area.
- 11) Once you've recorded all arthropods observed, and the plant information for the tree you surveyed, tap SUBMIT and move on to the next survey!

AT&T 63° 3:04

< Go back >

Add Arthropod Order Info ?

Ants (Formicidae) x

Length: 4
Count: 3
Notes:

Ants (Formicidae) x

Length: 10
Count: 1
Notes:

Caterpillars (Lepidoptera larvae) x

Length: 35
Count: 1
Notes:
Hairy or spiny: false
Leaf roll: false
Silk tent: true

< ○ □

AT&T 63° 3:10

< Go back >

Leaf Count
50

Herbivory

Please select an herbivory score.

	0 - None
	1 - Trace Less than 5%
	2 - Light 5% to 10%
	3 - Moderate 10% to 25%
	4 - Heavy Greater than 25%

SUBMIT

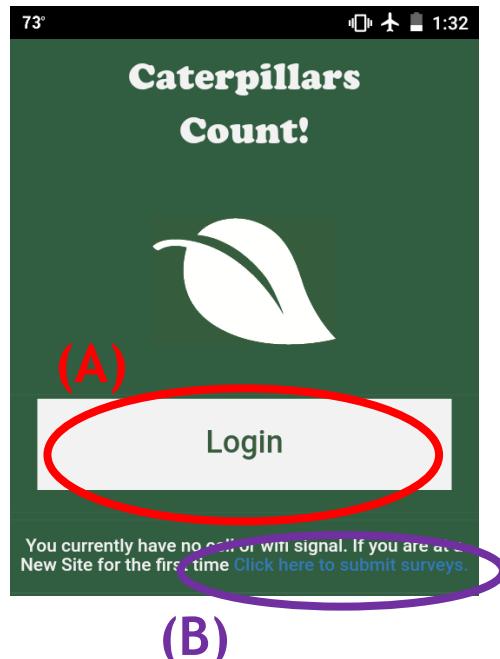
< ○ □

Conducting a Survey (without cell service)

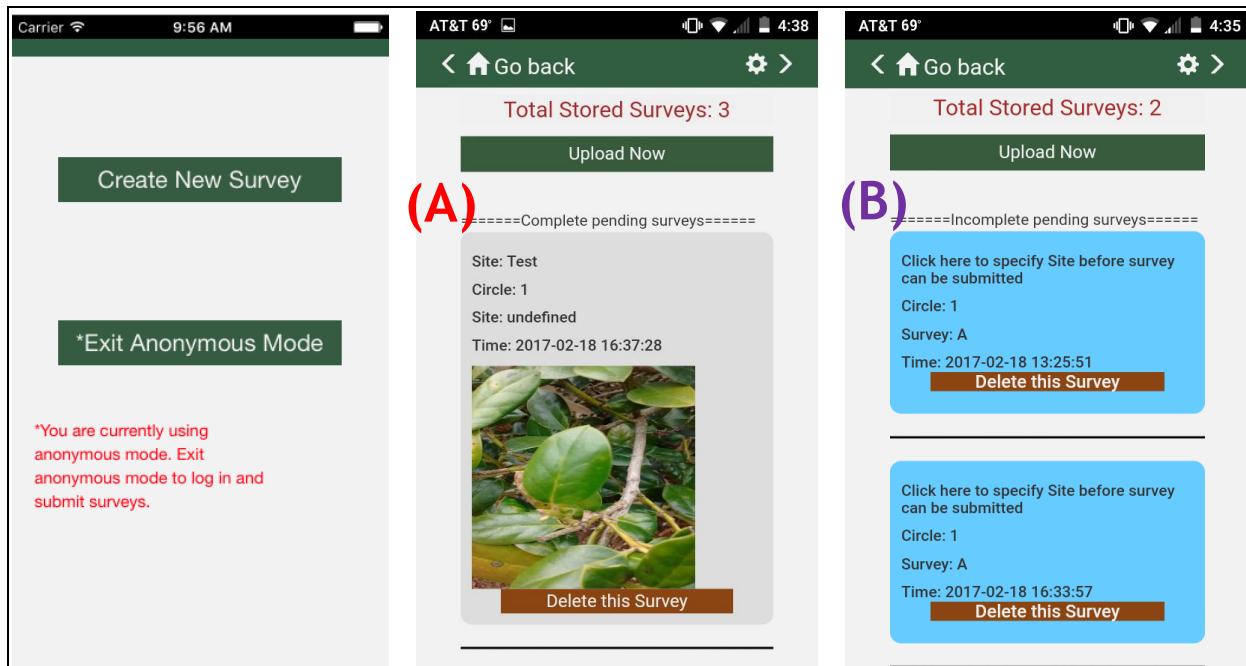
In an ideal world, every Caterpillars Count! site would have excellent WiFi coverage, and users would be able to submit each survey as soon as they complete it. Unfortunately, since many of our sites are in remote locations, many users have trouble maintaining strong cellular coverage, let alone WiFi.

(A) Assuming you have already added the site to your Site List while you were connected (see Add New Site, above), you can simply tap **Login** and **Create New Survey** and follow the instructions above. Without cell or WiFi service, your surveys will be automatically stored as "Pending Surveys". You can submit these surveys at your convenience whenever your device is back online by tapping the **Upload Now** button on the **Pending Surveys** page (A, below).

(B) If you have no cell service and have not yet added the site to your site list, you can still conduct a survey in "Anonymous Mode" by tapping the small blue text ("Click here to submit surveys") at the bottom of the home page. In this case, when you fill out a survey (by tapping Create New Survey) you will not specify Site (it will get saved as "Unknown Site") and it will get saved as an Incomplete Pending Survey (blue boxes, below). Once you have cell or WiFi service again, tap **Exit Anonymous Mode** and then you can add the Site to your Site List with the password given to you by the site coordinator. Then tap on each blue Incomplete Survey on the Pending Surveys page (B, below), specify the site and hit Submit.



(B)



USING A PAPER DATASHEET

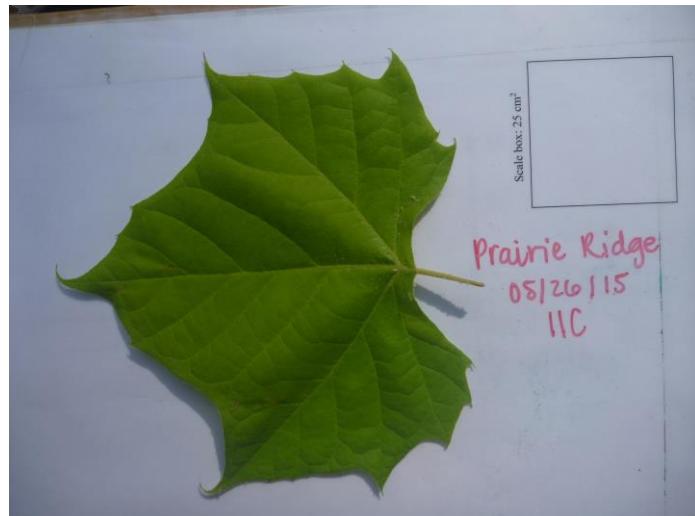
Caterpillars Count!

Foliage Survey Datasheet

Site Name:		Date:		Survey Type (Beat sheet / Visual)			
NC Botanical Garden		5/19/17		Beat			
Observer	AHH	Temp	75F	Site Notes: rained last night, wet leaves			
Time	Survey (1A, ...)	Plant species (if known)	Herb- ivory	Order	Length (mm)	#	Notes
915	1A	Red maple	3	Beetle	12	2	leaf count: 64
				Ant	3	1	

If you do not have access to a mobile device, you can record your observations using the Foliage Survey Datasheet available on the [Participate](#) page of the website.

- Begin a survey sheet:** Fill out the top of the datasheet (location, surveyor, date, time, temperature, survey type).
- Record the time** that you start each new survey
- Record the circle number and survey letter of your survey location.** (e.g., "1A")
- Determine and record the tree species.**
- Give your 50-leaf sample an **herbivory score** based on how much leaf damage there is (see #9 under *Conducting a Survey*, above).
- When you find an arthropod, **record the Order** it belongs to (e.g., beetle, caterpillar, fly, etc), its **body length** to the nearest millimeter, as well as the number observed (#).
- If you searched 50 leaves and did not find a single arthropod, we still want you to record that a survey was done!** Write "NONE" under Order. Otherwise, we will never know the difference between a survey that was never conducted, versus a survey with 0 abundance. Write 0 for the Length and Count as well.
- If you are doing beat sheet surveys, remember to **record the leaf count of your beat sheet sample** in the Notes field.
- When taking a **leaf photo** on the leaf photo scale sheet, be sure to include the site, date, and survey location. Leaf photos may be uploaded to a Dropbox folder (contact your site administrator).
- After completing your surveys, enter your data through the website by clicking on the [Submit Observations](#) tab.



TIPS FOR VISUAL SURVEYS

- Be sure to check both the **upper and lower sides** of every leaf in your survey carefully.
- Don't forget that the survey also includes the associated **twigs and petioles**, so scan those as well.
- Many arthropods are cryptically colored and can look just like the leaf or twig they are on—you will have to be vigilant!
- When doing a survey, **disturb the branch as little as possible**. If you move it too much, arthropods may fall off or fly away from the leaves you are hoping to survey.
- See here for a video demonstrating how to conduct visual foliage surveys:

<http://www.youtube.com/watch?v=XXWEwbRk9jU>



Note that the layout of surveys in the video differs; use the one specified in this document.

TIPS FOR BEAT SHEET SURVEYS

- Hold the beat sheet directly under a branch that has ~20-100 leaves on it.
- Whack the branch strongly enough to knock off arthropods, but not so strongly that twigs and leaves are damaged.
- A stick between $\frac{1}{2}$ - 1" in diameter works best.
- The branch should be whacked exactly **10 times**.
- Hold the beat sheet in one place during all 10 whacks.
- Spend at least a minute looking at your beat sheet—bugs that are small, or pale, or look like debris may not be obvious at first glance, especially if you are in poor light.
- Be aware that some insects may be knocked into your beat sheet very briefly but will then fly away. Try to identify and count any arthropods that might fly away first (e.g., flies, moths, beetles) before counting the more sedentary ones.
- After recording all of the arthropods that have fallen onto the sheet, **count the number of leaves on the branch that were directly above your beat sheet when you were beating**.



LESSON PLANS



EXPLORING CATERPILLARS COUNT! DATA

Whether or not you conducted your own Caterpillars Count! surveys, all of the data submitted by citizen scientists all over the country are available for exploring and visualizing. This type of data exploration can make for productive inquiry-based learning activities with students of almost any age, and can provide a nice classroom-based complement to the outdoor activities of the surveys themselves.

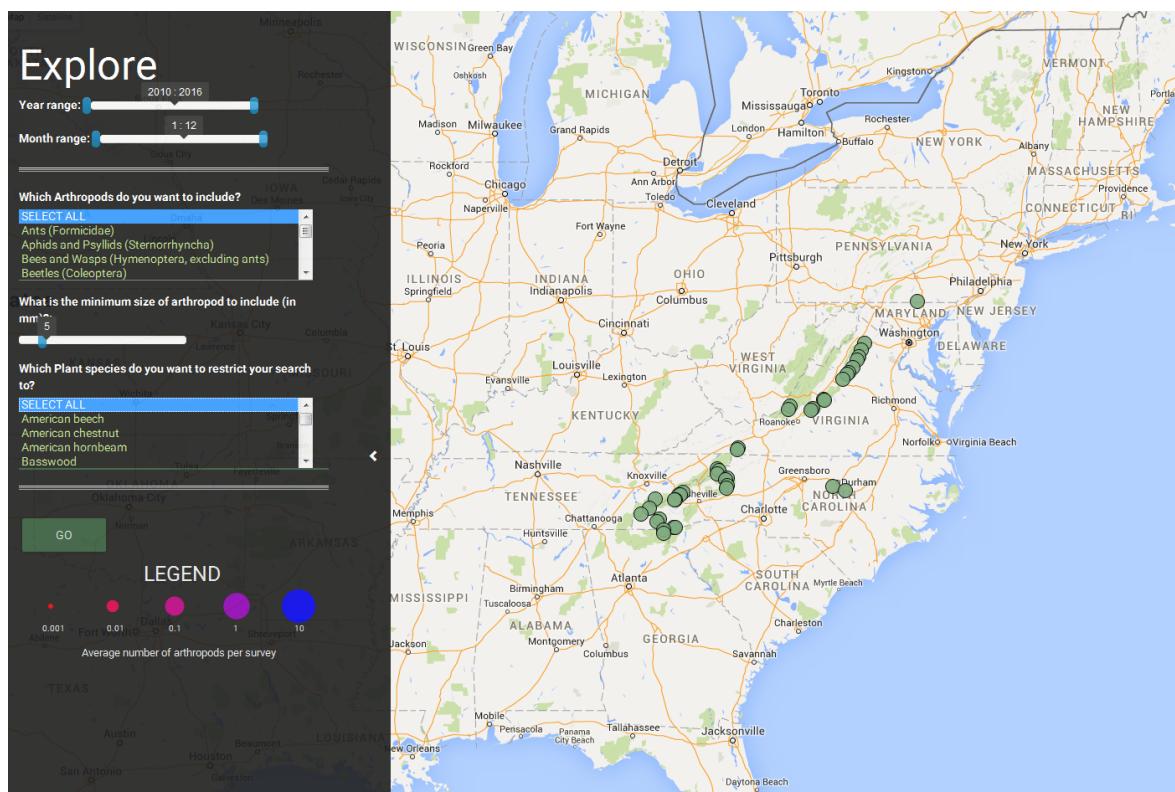
Below are instructions for the different types of data visualization available, the types of questions that may be asked and answered, as well as some background information for teachers that might be helpful for discussing student findings.

Data Visualization

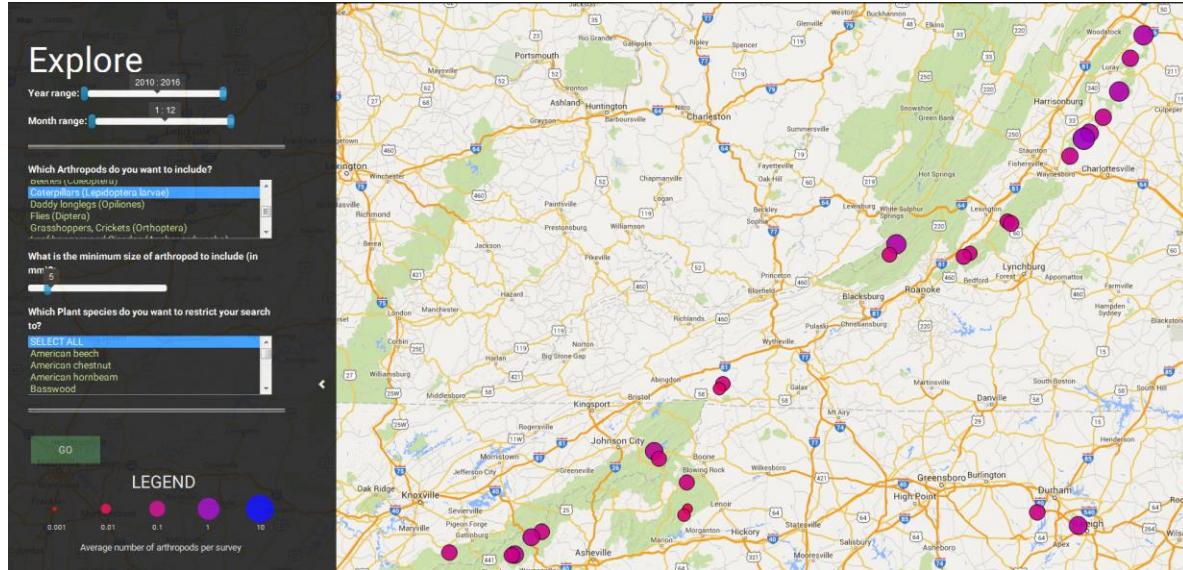
Data may currently be visualized in 3 distinct ways, all through the 'Explore Data' page of our website at <http://caterpillarscount.unc.edu/data/>. First, users may explore how the density of different types of arthropods varies geographically. Second, users may explore how the types of arthropods present varies based on the tree species that the survey was conducted on at a particular site. Third, users may explore the phenology, or seasonal timing, of different arthropod groups at a particular site.

Map-based Visualizations

Upon first loading the Explore Data page, you will see a map of all of the locations where Caterpillars Count! surveys have been conducted. These survey locations can be set so that the size and color of the map symbol reflects the average density (# per survey) of different arthropod groups.



- 1) Adjust the sliders to specify the year(s) and month(s) for which you'd like the data to display.
- 2) Select the Arthropod groups you'd like to include in your visualization. You may select multiple groups by holding down the Ctrl button while you click additional groups. The default is to 'SELECT ALL' arthropod groups.
- 3) Select the minimum size in millimeters that you are interested in summarizing. For example, you might decide you only want to know about arthropods larger than 10 mm. Alternatively, if you want to display data for all arthropods regardless of their size, set this slider to 0.
- 4) If you'd like, you can restrict your analysis of arthropod density to particular tree species. You may select multiple tree species by holding down the Ctrl button while selecting additional species. NOTE: You will quickly realize that not all tree species have been surveyed at every location!
- 5) Click "GO" to display average arthropod density for the arthropod groups and tree species that you selected. Larger, bluer symbols indicate higher densities, while smaller redder symbols indicate lower densities.



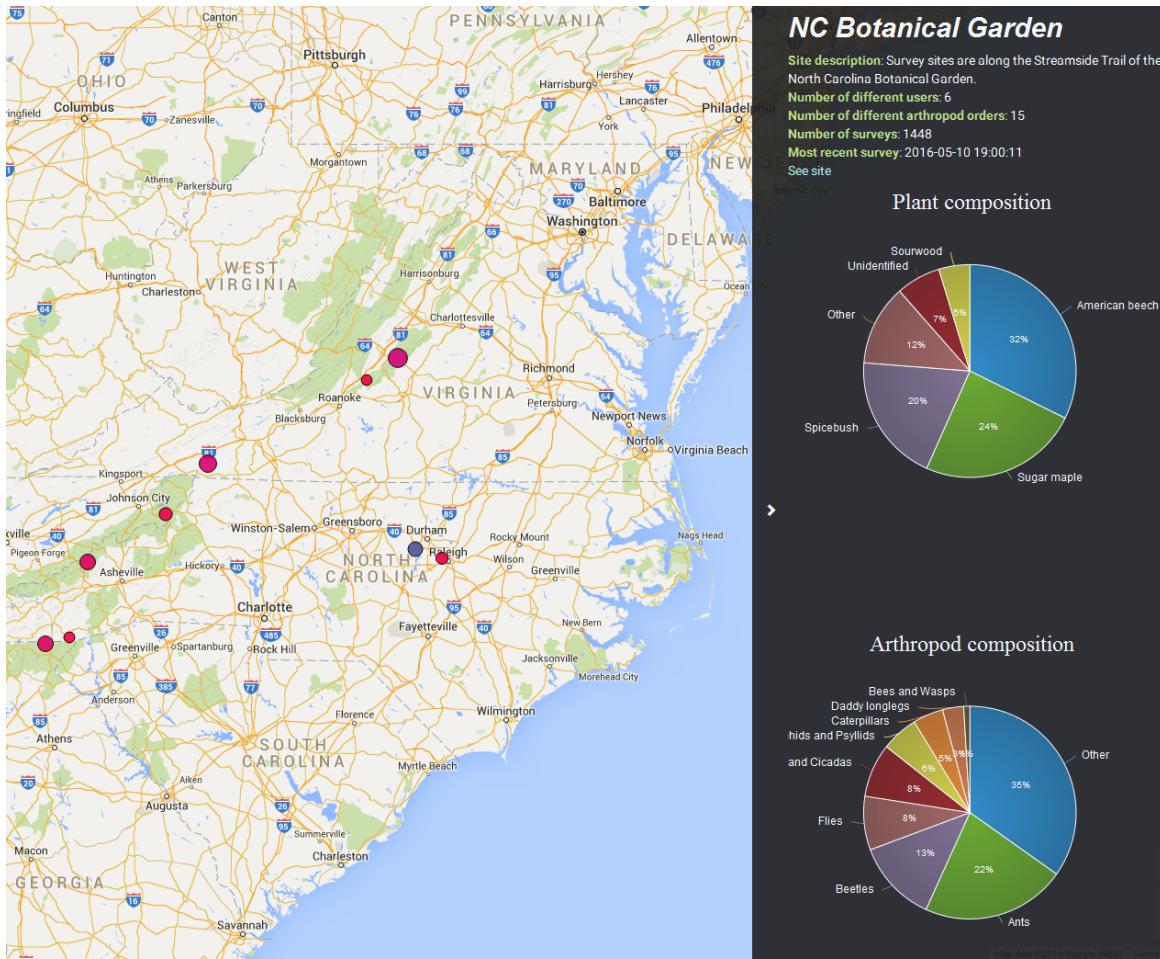
A map of average caterpillar density. Sites with larger, purpler symbols had more caterpillars.

Example questions that could be asked with this data visualization tool:

- *Which locations have the most caterpillars?*
- *How do patterns of arthropod density vary with tree species?*
- *Which locations have surveys conducted on red oak?*
- *How do patterns of beetle density vary when including all beetles, versus including only large beetles?*

Site-specific Visualizations

A user may explore several facets of the data collected at one particular site by clicking on that site on the map. In some cases when there are multiple sites located near each other on the map, it may be useful to zoom in first before clicking. Once you click on a site, a summary tab will open as shown in the figure below.



At the top you can see how many different participants have submitted data for this site, the total number of arthropod orders that have been observed, the total number of surveys that have ever been submitted for that site, and the date and time of the most recent survey submitted.

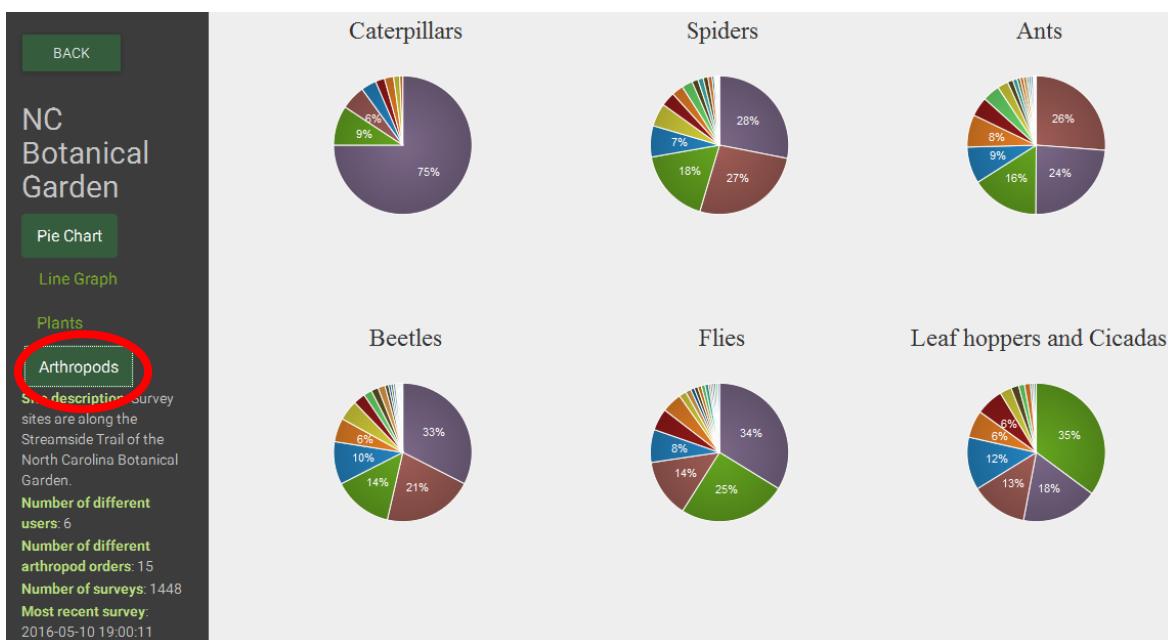
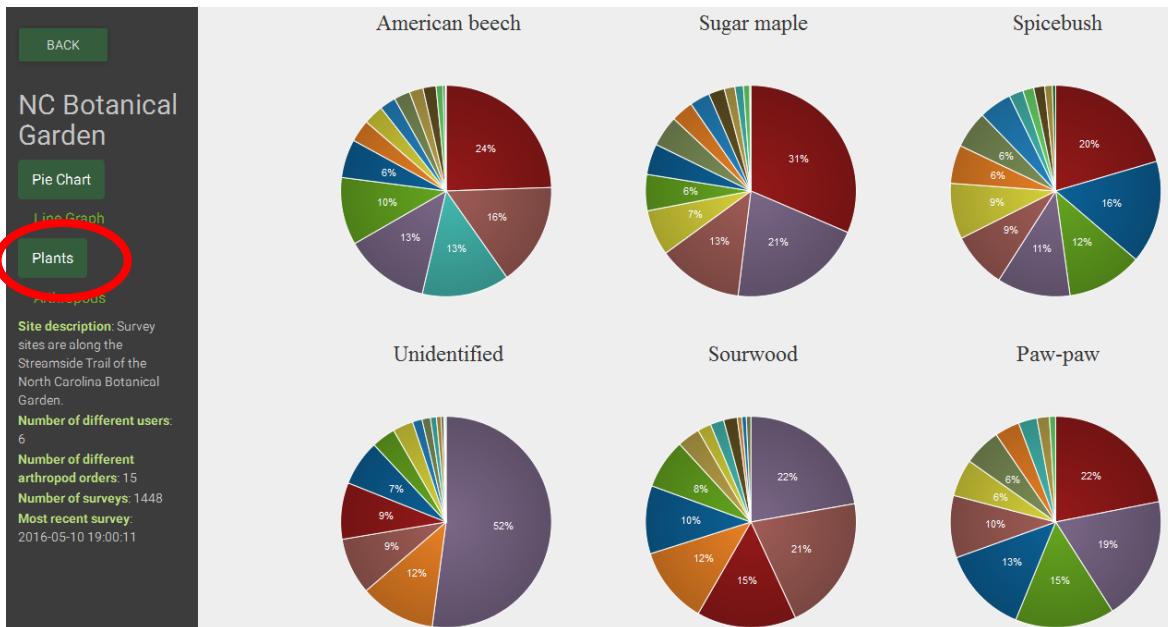
In addition the "Plant composition" pie chart illustrates the breakdown of tree species on which surveys have been conducted at that site. For the site above, most surveys have been conducted on American beech, sugar maple, and spicebush.

The "Arthropod composition" pie chart illustrates the relative frequency of the different arthropod groups at that site.

For more details about the site, click the "*See site*" link towards the top.

Pie Charts

These provide a more refined breakdown of the composition of different arthropod groups on different tree species. The default breakdown ("Plants") shows how the relative frequency of different arthropod groups varies by plant species. In the top panel below, the red color corresponds to Spiders (you can see what each color corresponds to by mousing over the pie charts), and you can see that 31% of arthropods on sugar maple were spiders, while only 15% of arthropods found on sourwood were. After selecting a breakdown by "Arthropods" (bottom panel), one can see that 75% of all caterpillars found occurred on American beech (in purple).

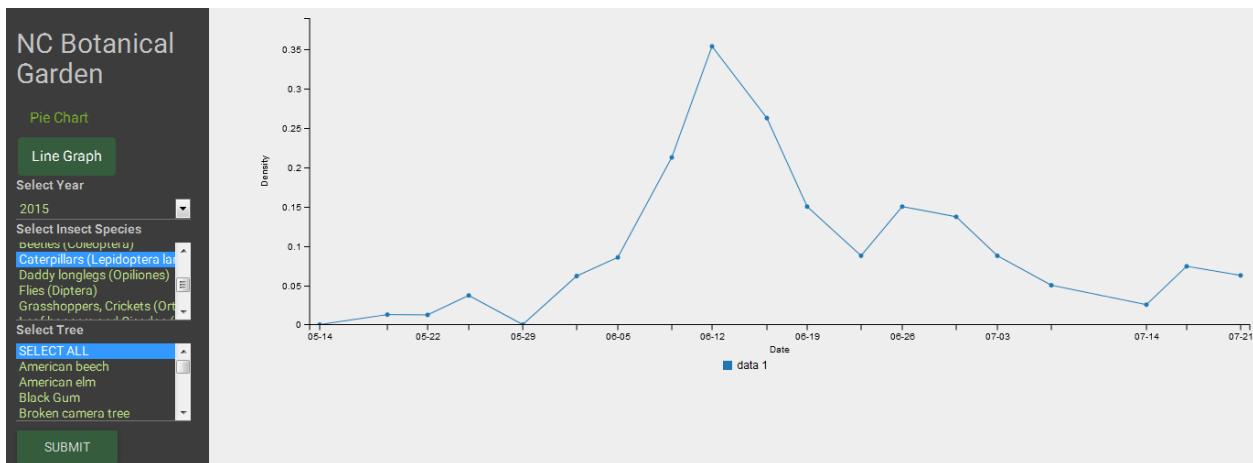


Example questions that could be asked with this data visualization tool:

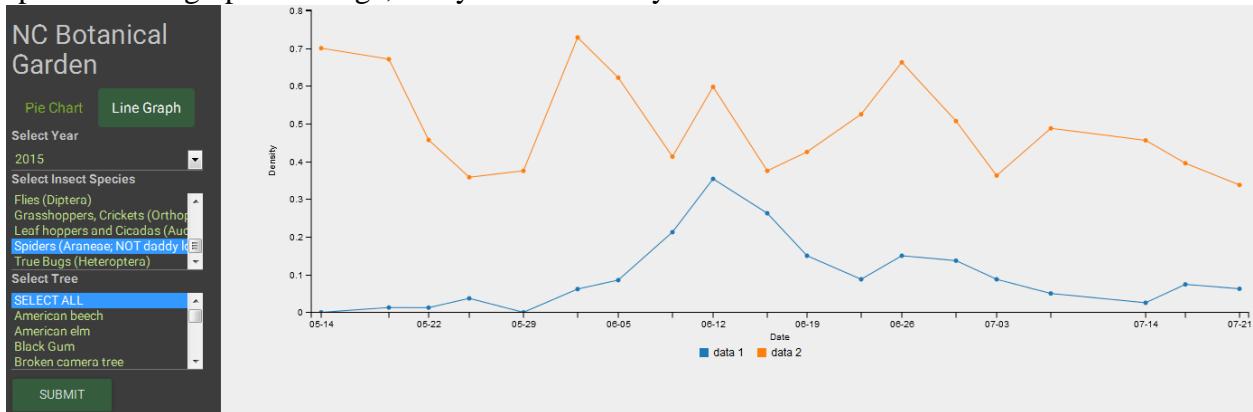
- *Which types of arthropods are most frequently encountered?*
- *Do spiders occur on some tree species more frequently than other tree species?*
- *How do American beech and sugar maple differ in terms of the types of arthropods that are found on their leaves?*

Line Graphs (Phenology)

Click on "Line Graph" on this Site Details page to view seasonal patterns of arthropod density. As on the Maps page, select the year, arthropod group or groups, and tree species that you would like to visualize. The graph below shows how caterpillar density varied from mid-May through late July in 2015 across all survey trees. Note the distinct peak in mid-June!



You may add additional lines to this graph for other groups within the same year by altering your selection of arthropod or tree species and clicking submit. Below, I've added the phenology of spiders to the graph in orange, and you can see they're much less seasonal.



Example questions that could be asked with this data visualization tool:

- *Which types of arthropods exhibit a seasonal peak in abundance?*
- *Is the timing of the peak consistent between years?*
- *Is the timing of the peak consistent between tree species in the same year?*
- *Is the timing of the peak consistent across different sites?*

Background Information for Instructor

Many of the patterns that will emerge from these data that you help collect have never been well described, so in many cases there is no "answer key"! The students or participants that you engage in this project are contributing important data that will help us better understand how foliage arthropods vary over time and across the map.

That said, here are some things we DO KNOW.

1. Seasonality

Just as leaves bud later and are on the trees for a shorter period of time farther north, we expect the same pattern for many insect groups. Temperature is expected to be a direct controller of both the timing of leaf out as well as insect development time. So expect to see peak densities of arthropods later at higher latitudes and elevations. The National Phenology Network (<http://www.usanpn.org>) has excellent resources and background information on phenology. See also our special Phenology Lesson Plan, linked on the [project website](#).

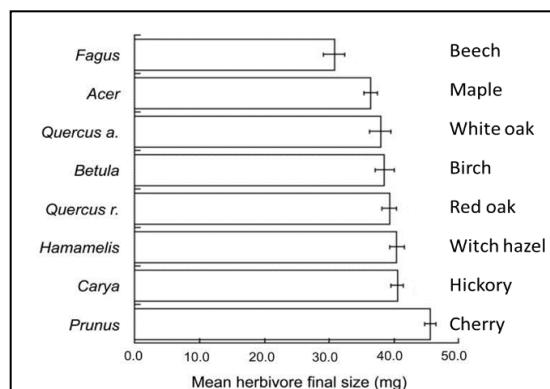
2. Trees as food

For some arthropods, trees and leaves are merely habitat—a place where they live, hide, and catch other types of food. Spiders and daddy longlegs are great examples of these types of arthropods. But for others, the leaves are not just their habitat, but also their food. Caterpillars, aphids, leafhoppers and many other

arthropods eat leaf tissue or suck plant juices.

But just as a twinkie, a hamburger, and a potato have different nutritional value to us, different tree species have different concentrations of proteins, carbohydrates, and potentially toxic secondary compounds that a given herbivore species may or may not have evolved to tolerate.

The graph at right shows an example of how different tree species differ in nutritional quality for caterpillars. The study is by Michael Singer of Wesleyan University, who showed that caterpillars raised on cherry tree leaves grow the most, ending at 45 mg before undergoing metamorphosis. In contrast, caterpillars fed only beech leaves grew to only 2/3 that size, a 33% reduction in growth! Tree species matters!



Caterpillar growth on different tree species. From Singer et al. 2012.

Tritrophic interactions at a community level: effects of host plant species quality on bird predation of caterpillars. *The American Naturalist* 179: 363-374.

If you observe much higher densities of certain arthropods on some tree species than others, perhaps it is because of such differences in nutritional quality. Only a controlled experiment will let you know for sure. Science project anyone?

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.



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.

¹ By Kevin Bolton [CC BY 2.0 (<http://creativecommons.org/licenses/by/2.0>)], via Wikimedia Commons

² By Daniel Spurgeon [GFDL (<http://www.gnu.org/copyleft/fdl.html>)], CC-BY-SA-3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>), via Wikimedia Commons

³ By Pollinator [GFDL (<http://www.gnu.org/copyleft/fdl.html>)], via Wikimedia Commons

PLANTS

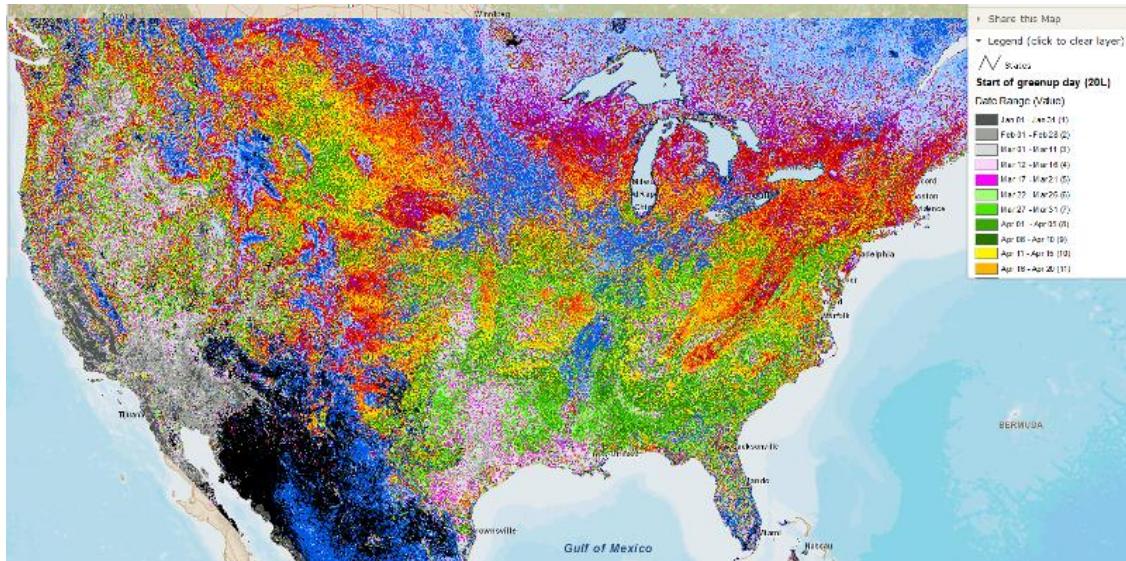
In order to get a grasp on the phenological events occurring in the plant world, we will use the U.S. Forest Change Assessment Viewer (<http://forwarn.forestthreats.org/fcav2/>) that allows us to see how the average “green-up” date—an estimate of the onset of spring—varies across the United States.

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?

BIRDS

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/>

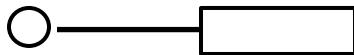
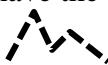
- A. Through trial and error, find three migratory bird species that are present in your state throughout the late spring and summer but that are absent in the winter.
- B. Using the animated occurrence maps for these species, determine the average arrival date of each species in your area based on the 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).
- Draw a vertical dashed line at the average green-up date based on #1.
 - Draw the flight chart for the butterfly species on the timeline below with a **solid line**.
 - 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.)
 - 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.



Mar Apr May June July August

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.

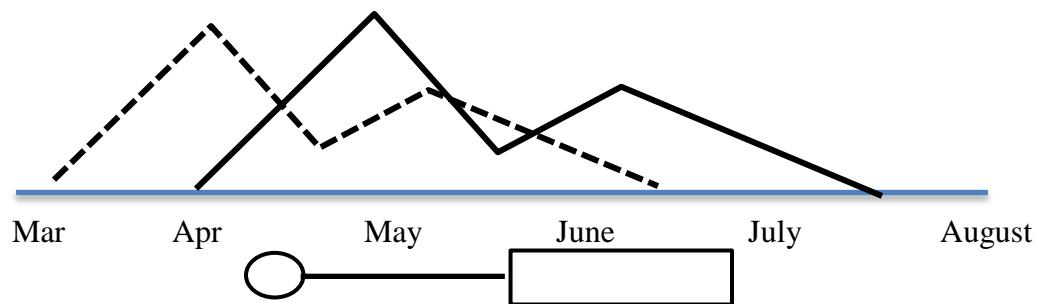
11. Choose the closest match between a bird species and a caterpillar (i.e., the predicted caterpillar activity based on the butterfly flight chart).

- Draw a vertical dashed line at the average green-up date based on #1.
- Draw the flight chart for the butterfly species on the timeline below with a **solid line**.

- 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.)

- 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.

ARTHROPOD LESSON TEACHER GUIDE

Age Range: Grades 6-9

Background: Learning about food webs is exciting, and can be supplemented with this arthropod activity. This activity allows students to see the interconnectedness of many of the organisms they encounter when they are outside.

Related NC Standards:

8.L.3- Understand how organisms interact with and respond to the biotic and abiotic components of their environment

8.L.3.3- Explain how the flow of energy within food webs is interconnected with the cycling of matter (including water, nitrogen, carbon dioxide, and oxygen)

6.L.2- Understand the flow of energy through ecosystems and the responses of populations to the biotic and abiotic factors of their environment

6.L.2.1- Summarize how energy derived from the sun is used by plants to produce sugars (photosynthesis) and is transferred within food chains to food webs (terrestrial and aquatic) from producers to consumers to decomposers

Materials Needed:

- Butcher paper
- Two different colors of printer paper
- Computer with printing capabilities
- Scissors
- Crayons
- Field guides (optional for learning about arthropods)
- Computers with internet access (optional for learning about arthropods)

Time Required: Approximately one hour (20 minutes for WANTED Posters and 40 minutes for the card sort)

Preparation:

- Print off 7 copies of the blank WANTED Poster
- Gather materials needed for students to fill out the posters
 - Crayons/markers
 - Field guides, our arthropod guide (find in the resources tab), etc.
- Print off 7 sets of the organism/action cards
- Gather materials needed for students to complete the card sort
 - Scissors (for cutting out the cards)
 - Markers (for drawing the arrows that connect the organisms)
 - Butcher paper (cut in ~2' x 3' rectangles)
 - Note: If cards are printed on heavier card stock, or are laminated, then they can easily be reused in future classes.

Day of Activity:

Wanted Posters

1. Start out by breaking students into 6 (or 7) groups. Allow students to come to the front of the room to grab their supplies for the WANTED Posters.

Group Assignments

Group 1: Spiders

Group 2: Aphids

Group 3: Caterpillars

Group 4: Bees

Group 5: Flies

Group 6: Ants

Group 7 (optional): Ladybird Beetles

2. Explain the process of looking for information about an arthropod. The main thing we are interested in is the diet of the arthropod, as this will best prepare the students for the next step of the activity. Look not only at what the arthropod eats, but also what eats the arthropod! If you choose to use computers during the search, it may be helpful to provide your students with a few useful links (these can be found at the end of this guide).
3. Explain the process of looking for information about an arthropod. The main thing we are interested in is the diet of the arthropod, as this will best prepare the students for the next step of the activity. Look not only at what the arthropod eats, but also what eats the arthropod! If you choose to use computers during the search, it may be helpful to provide your students with a few useful links (these can be found at the end of this guide).

- Once the students have gathered information, allow them to fill out their WANTED posters. Remind them to put useful information on the poster, but useful doesn't mean it can't be funny!

Example:

Name: Alice the Aphid

Wanted For: Sucking the sap out of poor innocent trees

Last Victim: Sally the Sycamore

- Once the posters are complete and you have checked over them for completeness, allow the students to do a brief presentation on their arthropod. Then, hang the posters on an empty wall in the classroom. This will allow the students to refer back to the information as they complete the next part of the activity.

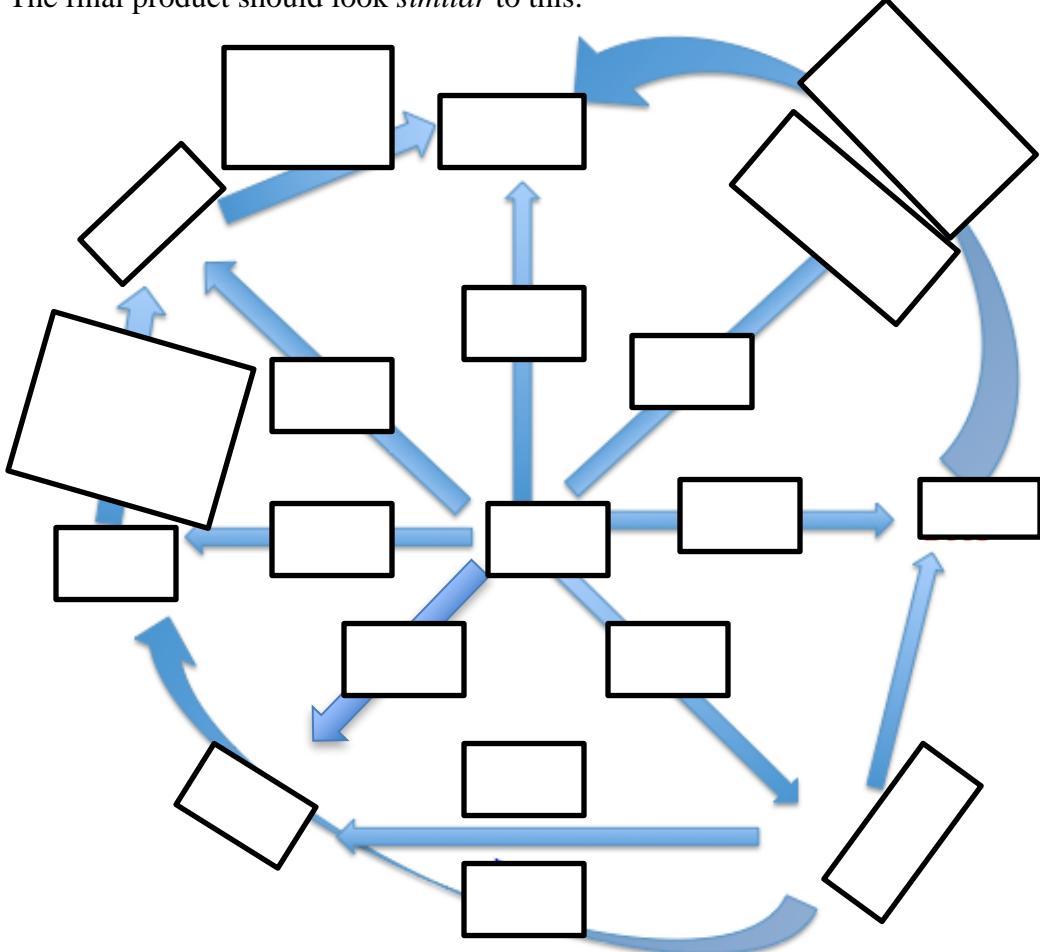
Arthropod Food Webs

- Break the students up into new groups so that each new group ideally has students who learned about each of the different arthropod types.
- Instruct the students to cut out the cards, keeping the organism cards separated from the action cards.
- Next, tell students to place the butcher paper on their desk. (the butcher paper should probably be ~2'X4', but if your students' desks are not this big simply allow them to pull their desks together, thus creating a larger space).
- Then, tell the students to place the ORGANISM cards on top of the butcher paper in any array they choose. It will be helpful, however, if the "bird" card is in the middle of the desk.
- Lastly, instruct students on how to connect the organisms using the actions. The organism → action → organism should make a sentence. For example, "Bees Pollinate Plants." The students should draw arrows between each organism and lay the action on top of the arrow.

Note: The direction of the arrows is very important, and should be taken into account!

For example: "cat → eats → mouse," not "mouse → eats → cat." The verbs and organisms remain the same, but the direction of the arrow makes a big difference!

The final product should look *similar* to this:



Checklist of Connections:

Birds → (eat) spiders, (eat) flies, (eat) caterpillars, (eat) ants, (eat) aphids, (eat) birds

Spiders → (eat) flies, (eat) ants, (eat) aphids, (eat) caterpillars

Caterpillars → (eat the leaves of) plants

Bees → (pollinate) plants

Flies → (eat microbes from the surface of) plants

Flies → (pollinate) plants

Aphids → (suck juices from) plants

Ants → (eat the honeydew produced by) aphids

Note: The highlighted actions above are optional. If you would like to talk about them in your class then feel free! Some of your students may indicate these as possible connections and they are correct in saying so. Also, the drawing above does NOT contain all of the possible interactions. It rather just gives you an example of the final product.

Discussion Questions:

1. How many organisms would be affected if spiders were removed from the food web? What if we removed plants instead?
2. What problems can you think of that might result from birds being removed from the food web? (Carrying capacity)
3. Does the food web continue on past birds?
4. How much energy is being transferred from one animal to the next as you move through the food web?

Useful Links:

Aphids	http://www.aphids.info (click on “About Aphids” at the top of the screen) https://www.youtube.com/watch?v=Dhi-SYxNPFw (short video on ant/aphid farming)
Bees	http://a-z-animals.com/animals/honey-bee/
Caterpillar	http://a-z-animals.com/animals/caterpillar/
Flies	http://a-z-animals.com/animals/fly/
Ants	http://a-z-animals.com/animals/ant/
Spiders	http://www.spiders.us/species/agelenopsis-spp/

EAT

EAT

EAT

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EAT

EAT

EAT

EAT

EAT	EAT THE LEAVES OF
POLLINATE	SUCK JUICES FROM
EAT MICROBES FROM THE SURFACE OF	EAT HONEYDEW PRODUCED BY
POLLINATE	EAT THE LEAVES OF

PLANTS	BIRDS
BEES	APHIDS
CATERPILLARS	ANTS
FLIES	SPIDERS

OTHER LESSON PLANS

Phenology

Suggested Grades: 6-12

Goal: Students gain practice in graphing while learning the difference between weather and climate

Note: Only pages 9-14 are suggested for this activity

Link: <http://www.nps.gov/grsm/learn/education/upload/MSPhenology.pdf>

Vernal Pool Data Analysis

Suggested Grades: 4-6

Goal: Students enhance their graphing skills while also learning about vernal pools in the Harvard Forest.

Link: <http://harvardforest.fas.harvard.edu/sites/harvardforest.fas.harvard.edu/files/data/k12/sy003/Vernal%20Pool%20Ruggles%202007.pdf>

How do Changes in Weather Affect Butterflies?

Suggested Grades: 9-12

Goal: Students practice statistical modeling while learning about the effects of weather on butterflies.

Link: <http://butterfly.ucdavis.edu/education/stat2>

Do Caterpillars Eat Faster When It's Hot Or Cold?

Suggested Grades: 6-8

Goal: Students will expand their graphing skills while simultaneously learning about the effects of temperature on *Manduca sexta* caterpillars.

Link: <https://sarahseiter.wordpress.com/education/>

Weather and Climate Data Exploration

Suggested Grades: 6-12

Goal: Students explore the relationship between weather and climate by graphing weather temperature data and comparing with climate averages.

Link: <http://scied.ucar.edu/activity/weather-and-climate-data-exploration>

OTHER RESOURCES



Dichotomous Keys to Arthropod Orders

Modified from the American Museum of Natural History

http://www.amnh.org/learn/biodiversity_counts/ident_help/Text_Keys/text_keys_index.htm

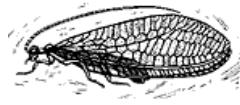
- Key A: Arthropods with Six Legs, with Well Developed Wings
- Key B: Arthropods with Six Legs, with Tiny or Missing Wings
- Key C: Arthropods with More Than Six Legs.

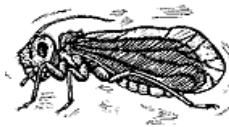
Orders important for Caterpillars Count! are highlighted in RED!

Tips: Only adult arthropods are included, and certain uncommon orders are not included. To use a key, read both descriptions in a couplet (for instance, 1a and 1b). Decide which sounds most like your critter, and move to the next couplet indicated. Should you reach a dead-end, use the numbers in parentheses to backtrack until you reach a couplet that you felt unsure about, and try following the other path. Some orders are found more than once in the keys, because the arthropods occur in different forms.

Key A: Arthropods with Six Legs, with Well-Developed Wings.

STEP	FROM	CHARACTERS	ORDER / CLASS
1a		One pair of wings. go to 2	
1b		Two pairs of wings. go to 3	
2a	1a	Hind wings reduced to tiny knobs (halteres), tip of abdomen without 2-3 thread-like tails	 DIPTERA (Flies)
2b	1a	Hind wings not reduced to tiny knobs, tip of abdomen with 2-3 thread-like tails (caudal filaments)	 EPHEMEROPTERA (Mayflies)
3a	1b	Front and hind wings have similar texture. go to 4	

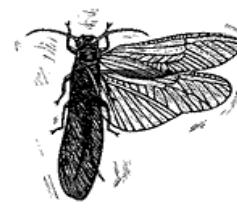
3b	1b	Front wings a rigid or leathery covering for clear hind wings. go to 14	
4a	3a	Wings covered with powdery scales, mouthparts usually a coiled tube (proboscis) for sucking	 <p>LEPIDOPTERA (Moths / Butterflies)</p>
4b	3a	Wings not covered with powdery scales, mouthparts not a coiled tube. go to 5	
5a	4b	Wings slope downwards (rooflike) from the center at rest. go to 6	
5b	4b	Wings not held rooflike at rest. go to 9	
6a	5a	Wings covered with hair	 <p>TRICHOPTERA (Caddisflies)</p>
6b	5a	Hairless wings. go to 7	
7a	6b	Sucking mouthparts in the form of a rigid beak, often short and bristly antennae, body may look like a thorn	 <p>AUCHEGORRHYNCHA (Hoppers, Cicadas)</p>
7b	6b	Mouthparts not in the form of a rigid beak, antennae not short and bristly, body never looks like a thorn. go to 8	
8a	7b	Wings with many cross veins	 <p>NEUROPTERA (Lacewings)</p>

8b	7b	Wings without many cross veins	
9a	5b	Front and hind wings similar in size and shape. go to 10	
9b	5b	Front and hind wings not similar in size and shape.go to 12	
10a	9a	Antennae always short and bristley	
10b	9a	Antennae never short and bristley. go to 11	
11a	10b	Wings held flat over abdomen when at rest, last abdominal segment not enlarged, usually found in colonies	
11b	10b	Wings not held flat over abdomen when at rest, males with the last abdominal segment enlarged like a scorpion's stinger and held over the body, not found in colonies	
12a	9b	Body very soft, without a narrow "waist". go to 13	



12b 9b Body not exceptionally soft, often with a narrow "waist"

HYMENOPTERA
(Bees & Wasps)

13a	12a	Hind wings wider than front wings, folded underneath like a fan	
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PLECOPTERA
(Stoneflies)

13b	12a	Hind wings much smaller than front wings, not folded underneath like a fan	
-----	-----	--	--

EPHEMEROPTERA
(Mayflies)

14a	3b	Sucking mouthparts in the form of a rigid beak, front wings with clear tips (hemelytra), overlapping at rest, revealing a triangular panel on the back (scutellum)	
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HETEROPTERA
(True Bugs)

14b	3b	Cheching mouthparts, front wings without clear tips. go to 15	
-----	----	--	--



COLEOPTERA
(Beetles)

15a 14b Rigid front wings (**elytra**) meet in a straight line down the middle of the back

15b	14b	Front wings not as above. go to 16
16a	15b	Head visible from above. go to 17

16b	15b	Head hidden from above by a hoodlike structure (pronotum)	 BLATTARIA (Cockroaches)
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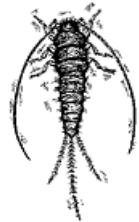
17a	16a	Front legs strong with prominent spines for grasping prey, hind legs long and slender	 MANTODEA (Mantids)
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17b 16a Front legs without spines or with weak spines, the femora of the hind legs are enlarged for jumping

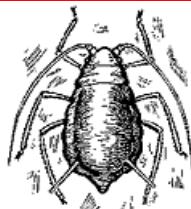


ORTHOPTERA
(Grasshoppers & Crickets)

Key B: Arthropods with Six Legs, with Tiny or Missing Wings.

STEP	FROM	CHARACTERS	ORDER / CLASS
1a		Does not resemble a twig. go to 2	
1b		Slow-moving, resembles a twig	 <p>PHASMIDA (Walking sticks)</p>
2a	1a	Body very soft. go to 3	
2b	1a	Body not exceptionally soft. go to 8	
3a	2a	Mouthparts hidden within head, usually with a springlike structure (furcula) on the underside of the abdomen used for jumping	 <p>COLLEMBOLA (Springtails)</p>
3b	2a	External mouthparts, without a springlike structure on the underside of the abdomen. go to 4	
4a	3b	Visible projections at the tip of the abdomen. go to 5	
4b	3b	No visible projections at the tip of the abdomen. go to 6	
5a	4a	Long flattened body, tip of abdomen with 2 - 3 long tails (cerci , and if a third tail is present, a median caudal filament)	 <p>THYSANURA (Silverfish)</p>

5b **4a** Small pear-shaped body, tip of abdomen has two short projections (**cornicles**), some individuals have wings



STERNORRHYNCHA
(Aphids)

6a	4b	Usually found in colonies with many individuals (soldier caste), some of which have very large heads and mandibles (soldier caste) or mouthparts that look like a tube (nasuti caste)	 ISOPTERA (Termites)
6b	4b	Tiny insects that may be found in groups of many individuals, but they all have the same kind of mouthparts go to 7	

7a	6b	Chewing mouthparts, relatively long antennae, when individuals have wings the wings never have fringes of hair	 PSOCOPTERA (Bark lice)
7b	6b	Sucking mouthparts, fairly short antennae, adults may actually have barely visible wings with fringes of hair	 THYSANOPTERA (Thrips)

8a **2b** Body with a narrow "waist," antennae usually have a bend in the middle



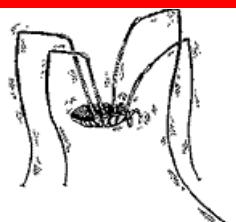
HYMENOPTERA
(Ants)

8b	2b	Body without a narrow "waist", antennae don't usually have a bend in the middle. go to 9	
9a	8b	Tiny jumping parasites found on mammals or birds, where they suck blood	 <p>SIPHONAPTERA (Fleas)</p>
9b	8b	Not found on mammals or birds, chewing mouthparts. go to 10	
10a	9b	Prominent "pincers" at the tip of the abdomen (cerci)	 <p>DERMAPTERA (Earwigs)</p>
10b	9b	Without "pincers" at the tip of the abdomen	 <p>COLEOPTERA (Beetles)</p>

Key C: Arthropods with More Than Six Legs.

STEP	FROM	FEATURES	ORDER / CLASS
1a		Four pairs of legs. go to 2	
1b		More than four pairs of legs. go to 6	
2a	1a	Abdomen with distinct segments. go to 3	
2b	1a	Abdomen without distinct segments. go to 5	
3a	2a	Conspicuous "pincers" (pedipalps) in front of shorter legs. go to 4	

3b 2a Without "pincers," long and slender legs



OPILIONES
(Daddy-Longlegs)

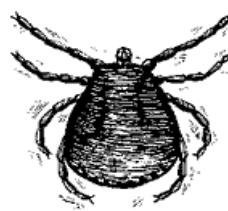
4a	3a	Fairly large, the abdomen ends in a stinger	 SCORPIONES (Scorpions)
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4b	3a	Small, the abdomen does not end in a stinger	 PSEUDOSCORPIONES (Pseudoscorpions)
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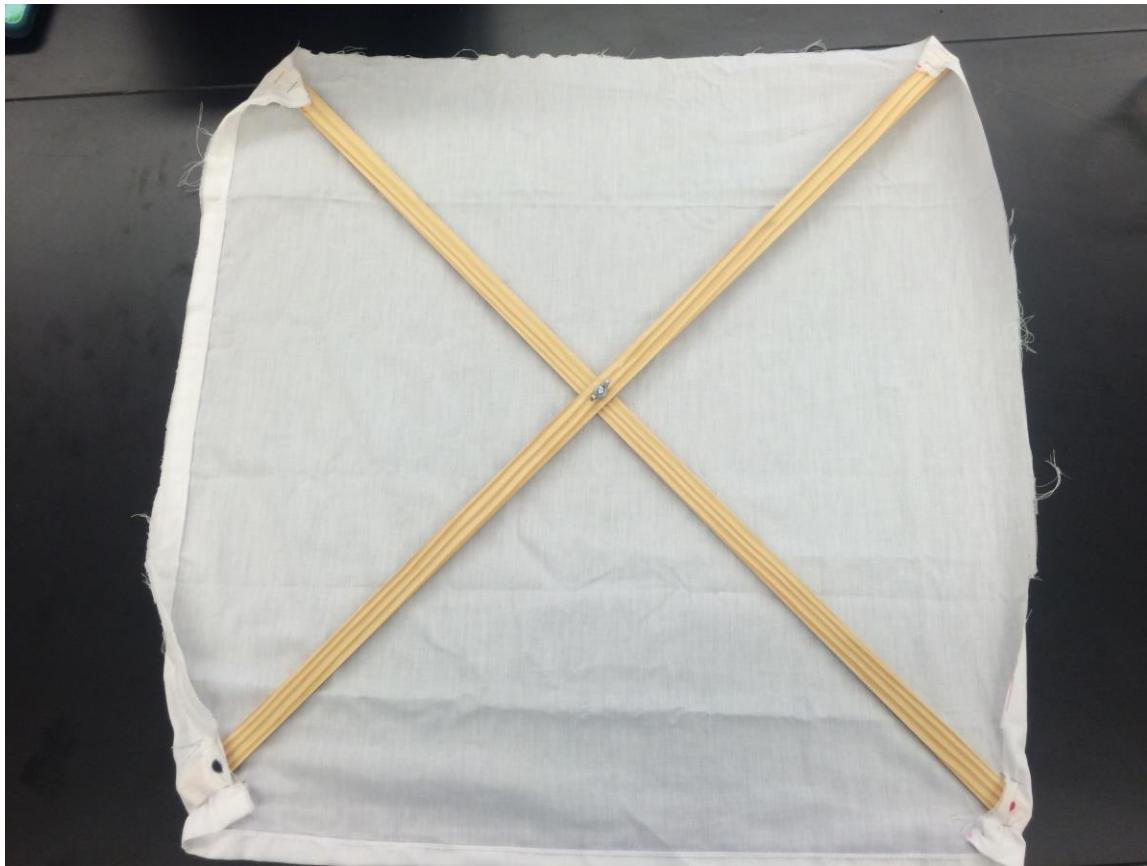
5a 2b Body clearly divided into two main parts
(cephalothorax and abdomen)



ARANEAE
(Spiders)

5b	2b	Oval-shaped body not divided into two main parts	 <p>ACARI (Mites & Ticks)</p>
6a	1b	Seven pairs of tiny legs, some roll up into balls	 <p>ISOPODA (Pillbugs, sowbugs)</p>
6b	1b	More than seven pairs of legs, they don't roll up into balls. go to 7	
7a	6b	Tiny bodies, 10 - 12 pairs of legs	 <p>SYMPHYLA (Symphylans)</p>
7b	6b	Bodies often fairly large, with > 15 pairs of legs. go to 8	
8a	7b	Flattened bodies, with one pair of legs attached to each body segment	 <p>CHILOPODA (Centipedes)</p>
8b	7b	Bodies usually tubelike, with two pairs of legs attached to each body segment	 <p>DIPLOPODA (Millipedes)</p>

Creating Your Own Beat Sheet



Beat sheeting is an alternate way of surveying arthropod activity. This method is more time efficient and could be best utilized for people working with young kids. This method does not require individually turning over 50 leaves and therefore takes much less time and effort.

How to conduct a beat sheet survey:

Hold your beat sheet under a branch or bush. Use a stick (a diameter of 1/2" – 3/4" works best) and vigorously beat the bush 10-15 times with the stick. See what cool arthropods fall into your beat sheet!

Materials Needed:

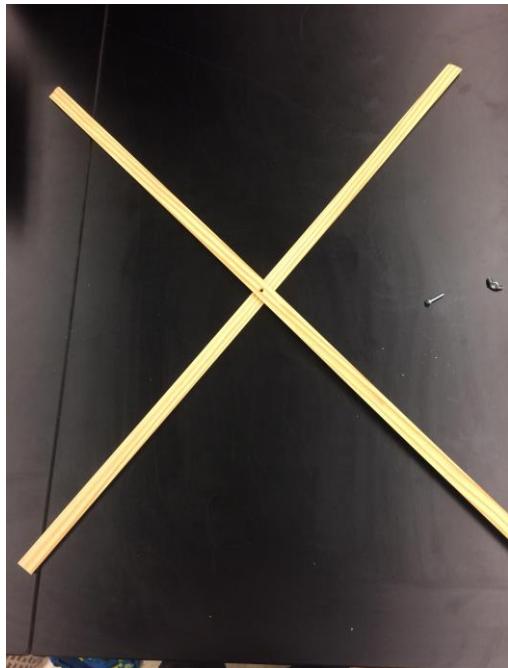
- 10 ft. strips of $\frac{3}{4}$ " molding (each 10 foot strip will yield two beat sheets)
- Wing nuts and screws with sizes that complement one another
- Drill (with a bit that complements the size of screw selected for the beat sheet)
- Tape measure
- Flat, white sheet (each beat sheet you make will require a 2' x 2' square of fabric)
- Two different colored permanent markers
- Stapler
- Hand saw

Time to Complete: About 30 minutes

Step 1: Using your hand saw, cut your 10' strips of molding into halves, and then into quarters. This should yield 4 pieces of 2.5 feet each). *Note: Your home improvement store may be able to complete this step for you!*

Step 2: For each beat sheet you are making, gather two 2.5 foot pieces. Using the drill, make a hole in the center of each of the pieces (at 1' 3").

Step 3: Lay one 2.5 foot piece on top of the other, with the holes aligned.



Step 4: Put the screw through *both* holes. Then, attach the wing nut.



Step 5: Take the flat white sheet and cut out a square 2 feet on a side, one for each beat sheet.

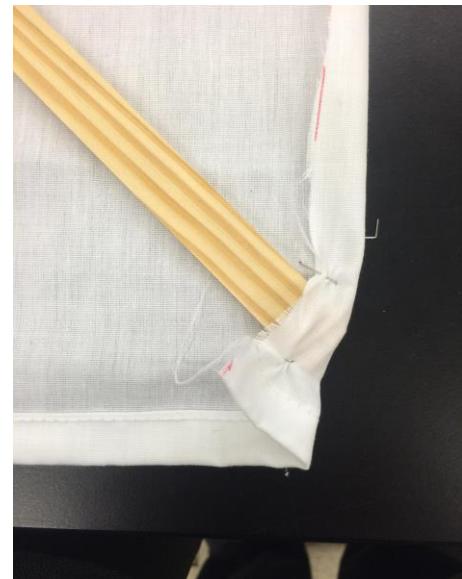
Step 6: Lay the square on a flat surface. Then, place your “X” in the center of the square. The wing nut should be facing *away* from the fabric, allowing you to adjust the tension in the “X.”



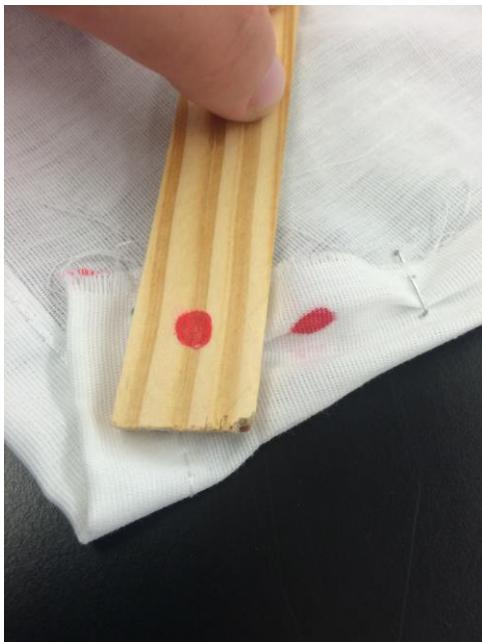
Step 7: Two corners of the wood will be permanently fixed to the fabric. In order to do this, you will fold two corners of fabric over two corners of the wood frame and staple the fabric into the wood. *Note: It does not matter which two corners you choose to be fixed, but they must be adjacent to one another.*



Step 8: The remaining two corners of fabric will be folded over to create pockets for the remaining two corners of wood. Simply grab a corner of fabric and fold it over the wood, making a pocket. The pocket should be snug around the wood, but not too tight. Then, staple the fabric in place. *Note: These staples go through the fabric only!*



Step 9: Optionally, you may draw dots of different color on each of the pockets and their corresponding wooden ends. This will serve as a visual reminder of how to set up the beat sheet properly.



Step 10: Take the wood corners out of the pockets and collapse the “X.” Now, your beat sheet is easy to carry and you can be off on your first beat sheeting adventure.

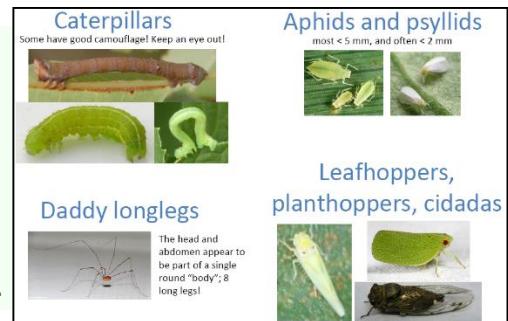


Tips for administering a Caterpillars Count! site

Training participants

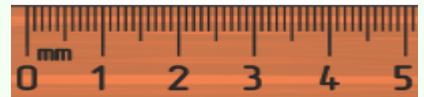
Arthropod identification

- Encourage participants to become familiar with the common arthropod orders before conducting surveys.
- Have them take the [Arthropod Photo ID Quiz](#) on our website until they can get at least 9/10 correct consistently.
- Print [2-sided ID guides](#) for participants to bring out in the field.



Estimating arthropod length

- Make sure that participants are comfortable estimating lengths **in millimeters**.
- Have them familiarize themselves with basic reference points, like the length of their pinky fingernail, length to first or second knuckle, etc.



Using the app

- Participants should use the mobile app to submit data if possible.
- If your site has limited cell service or if participants will be using devices without cell service, they should be sure to use the **Add New Site** feature to add your site to the app using the site password you provide them. This needs to be done under either a wifi or cell connection, so prior to coming out to the site.
 - For sites without cell service, surveys will be stored and can be submitted later when the user has an internet connection. See the [App User Manual](#) for details.
- Encourage participants to opt in to (1) using cellular data to submit surveys if applicable, and (2) submitting their arthropod observations to iNaturalist.org. Both of these options are on the Setting page reached by tapping the gear in the top right.
- If participants are not able to use the app, make sure it is clear who (the individual participants, or you, the site administrator) will be entering data from the datasheets into the [website](#).

The screenshot shows the app's "Site Information" screen with the following fields:
- Top bar: Back button, gear icon, "Go back".
- Temp.: Placeholder box.
- Time: Placeholder box showing "10:04 AM".
- Date: Placeholder box showing "Nov 6, 2016".
- Scan QR Code button.
- Site dropdown menu: "Please select a site".
- Survey Type dropdown menu: "Please select a survey type".
- Circle dropdown menu: "Please select a circle".
- Survey dropdown menu: "Please select a survey".
- Notes text area.



Tips for administering a Caterpillars Count! site

Training participants, continued

Tips for Beat Sheet Surveys

- Whack the branch strongly enough to knock off arthropods, but not so strongly that twigs and leaves are damaged.
- The branch should be whacked exactly **10 times**.
- Hold the beat sheet in one place during all 10 whacks.
- Spend at least a minute looking at your beat sheet—bugs that are small, or pale, or look like debris may not be obvious at first glance, especially if you are in poor light.
- Be aware that some insects may be knocked into your beat sheet very briefly but will then fly away. Do you best to estimate their type and length.



Tips for Visual Surveys

- Be sure to check both the **upper and lower sides** of every leaf in your survey carefully.
- Don't forget that the survey also includes the associated **twigs and petioles**, so scan those as well.
- Many arthropods are cryptically colored and can look just like the leaf or twig they are on—you will have to be vigilant!
- When doing a survey, **disturb the branch as little as possible**. If you move it too much, arthropods may fall off or fly away from the leaves you are hoping to survey.



General Tips

- Arthropod length is from the **head to the abdomen**—we don't count the length of legs or antennae.
- We only care about arthropods **2 mm long or longer**. So don't spend time sweating the small stuff!
- It's ok to call something '**UNIDENTIFIED**'! Better to record it as unidentified than to not record it at all!
- Taking photos of the arthropods you find within the app is optional, but **we strongly encourage photos of caterpillars!**



Tips for administering a Caterpillars Count! site

Curating data

At the end of each survey day, site administrators should check that the expected number of surveys was successfully entered into the database. Common errors that we like to catch are

- (i) a survey was mislabeled, so that, e.g., there are 2 entries for survey 1D but none for 1E;
- (ii) (ii) a survey was skipped accidentally, or
- (iii) (iii) a duplicate survey was accidentally submitted.

To curate data:

1. Log in to the [Administration](#) tab on the website.
2. Click 'Curate Data' on the left-hand side. You will see a list of sites you administer.
3. Clicking on the table icon (grid icon) under 'New Data' will provide a list of dates on which surveys were carried out.
4. Select a checkbox for the date to curate and then click 'View Surveys' at the top right.

Sites					
Name	State	Description	# Circles	New Data	
Prairie Ridge	NC	Prairie Ridge Ecostation is an outdoor nature center, part of the NC Museum of Natural Sciences, with 45 acres of Piedmont prairie, forest, ponds, a stream and sustainable building features integrated with a wildlife-friendly landscape.	8		
Prairie Ridge - New Data					
Survey Date		Total number of Surveys			
<input type="checkbox"/>	2014-07-24	19			
<input type="checkbox"/>	2014-08-05	40			
<input type="checkbox"/>	2014-08-19	38			

When there are no issues:

At the top of the new page, you'll find a series of **data checks** that ideally looks like this:

Rule	Status	Notes
Expected 20 Surveys		
Are there 4 Circles?		
5 surveys for each Circle?		
1 Entry for each Circle-Survey		

In this case, it is showing that one survey was submitted for every survey location in each of the survey circles established at the site. Great!

Because there were no errors, you can go ahead and click 'Mark all as Valid' at the top of the table below which lists every survey event on that date. Data curation is done!

Tips for administering a Caterpillars Count! site

Curating data, continued

When there ARE issues:

If there are missing or duplicate surveys, the **data checks** might look like this:

Rule	Status	Notes
Expected 20 Surveys	✗	21 surveys detected, 20 surveys expected
Are there 4 Circles?	✓	
5 surveys for each Circle?	✗	Circle #2 has 6 values
1 Entry for each Circle-Survey	✗	Survey 2A has 2 entries, Survey 4B is missing, Survey 4D has 2 entries

In this case, it is showing that surveys were submitted from 4 different survey circles as expected (✓), but that there was an extra survey submitted in Circle #2. The last row provides the most detail,

and tells us that in addition to the duplicate survey 2A, there was both a duplicate and a missing survey in Circle #4—most likely 4B was surveyed but incorrectly labeled 4D.

In the example above, we would have two things to fix. First, remove the duplicate entry for 2A, and second, switch the survey letter of the appropriate survey from 4D to 4B. Both of these can be accomplished by examining the list of all surveys submitted on that date below the data check table. Note that you can view the arthropods observed on any particular survey by clicking the black table icon (grid) toward the right side of that survey's row, although those arthropod data may not be edited*.

Site: NC Botanical Garden on Date(s): 2017-05-04											Go Back	Mark all as Valid	
Site ID	user	Circle	Survey Date/Time	T.	T.	Plant	Official	Site	mod	Survey Leaf	Photo	Herbivory	Status
8892356	Allen Hurlbert	1	D	2017-05-04 08:29:19	60	69	Paw paw	Paw paw		N/A	1	new	
click to expand													
Arthropod Data for Survey #26950													
Order Arthropod			Length			Notes			Count			Photo	
Ants (Formicidae)			4						2			N/A	
True Bugs (Heteroptera)			2						1			N/A	
Aphids and Psyllids (Sternorrhyncha)			2						1			N/A	
8892356	Allen Hurlbert	1	A	2017-05-04 08:33:19	60	69	Spicebush	Spicebush		N/A	0	new	
click to edit survey status or letter													

Clicking the edit button (at the right-hand side of the survey's data row, after which an **Edit Record** box will pop up with that survey's details. For our first error, we would decide which 2A survey should be discarded, and under '**Status**' select 'invalid'. For the mislabeled 4D survey, we can open the **Edit Record** box and switch the Survey letter to B.

*At the moment, clicking here will return an error if no arthropods were observed. That's ok, just click cancel.

Using the Caterpillars Count! mobile app

1. Before conducting surveys

- Download the Caterpillars Count! app (Google Play or iTunes), register (if necessary), and login.
- Click **Add New Sites** from the home screen, find your site in the dropdown menu, and then click the **Add New Site** button to enter the **site password** provided by your local coordinator.
- Click on the **Settings** gear () to configure settings—we recommend 'Yes' for both options.

2. Conducting surveys with cell / wifi

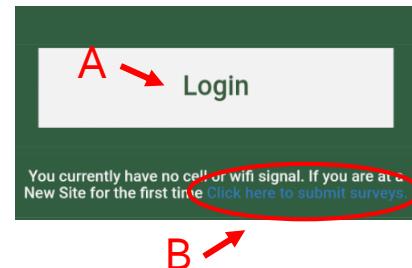
- Click **Create New Survey** from the home screen, and scan QR code or manually enter Site, Circle, and Survey information.
- For every arthropod type and size observed, click the **Add** button next to 'Arthropod Order Info', and specify the order, length, and count.
- Arthropod photos are optional; photos can be sent to iNaturalist.
- For beat sheet surveys, enter a **leaf count** for your survey.
- Characterize the **herbivory** of your survey branch.
- Take a photo of an average-sized leaf from your survey using the [Leaf Photo Scale Sheet](#).
- Submit! (if you see a strange error, try restarting your device)

The screenshot shows the 'Site Information' screen of the app. At the top, there are three buttons: 'Temp.', 'Time' (showing 2:31:31 F), and 'Date' (showing 05/05/20). Below these are several dropdown menus: 'Site' (set to 'Please select a site'), 'Circle' (set to 'Please select a circle'), 'Survey' (set to 'Please select a survey'), and 'Survey Type' (set to 'Please select a survey type'). There is also a 'Notes' field at the bottom.

3. Conducting surveys WITHOUT cell / wifi

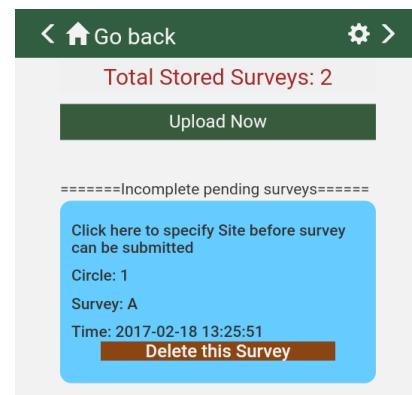
A) User has completed steps in Part 1

- Tap **Login**, and **Create New Survey** and follow instructions in Part 2.
- Survey will be stored as a **Complete Pending Survey** (gray box).
- When your device is back online tap **Upload Now** on the **Pending Surveys** page, and all surveys will be submitted to the database.



B) User has NOT added the Site to the app in advance

- On the Login page, click the blue text at the bottom to get started.
- Site will be 'Unknown' in offline mode, even after scanning QR code.
- After submitting the survey, it will be stored as an **Incomplete Pending Survey** (blue box).
- When your device is back online, **add the site** to the app as in Part 1.
- Tap each incomplete survey, specify Site from the dropdown, and Submit. These are now **Complete Pending Surveys**.
- You can now tap **Upload Now** and all surveys will be submitted.



See the full App User Manual for details:

caterpillarscount.unc.edu/participate