A Guide to Exploring *Caterpillars Count!* Data

Whether or not you conducted your own *Caterpillars Count!* surveys, all of the data submitted by citizen scientists from all over 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 from the **Maps & Graphs** page (https://caterpillarscount.unc.edu/mapsAndGraphs), 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.

Leaderboard

Keep track of your progress relative to other survey sites throughout the year by checking out the Leaderboard.

	Site name	SURVEYS THIS...			Caterpillars
		Week	**Month**	**Millennium**	
1	CawCaw Interpretive Center (SC)	36 1 survey date(s)	214 5 survey date(s)	397 15 survey date(s)	5.29%
2	Museum of American Bird Art (MA)	30 1 survey date(s)	150 5 survey date(s)	399 14 survey date(s)	19.8%
3	Hemlock Bluffs (NC)	25 2 survey date(s)	76 4 survey date(s)	645 21 survey date(s)	0.31%
4	Sault College (ON)	0 0 survey date(s)	60 2 survey date(s)	400 10 survey date(s)	10.75%
5	Kalamazoo Nature Center (MI)	0 0 survey date(s)	60 2 survey date(s)	363 14 survey date(s)	2.2%
6	Georgetown (DC)	0 0 survey date(s)	39 2 survey date(s)	370 14 survey date(s)	8.38%
7	The Children's Museum (CT)	0 0 survey date(s)	30 2 survey date(s)	127 9 survey date(s)	0.79%
8	Currituck Banks Reserve (NC)	0 0 survey date(s)	30 3 survey date(s)	110 11 survey date(s)	3.64%

You can sort the **Leaderboard** by *Site* or by individual *User*. Click on the column headers to sort by the number of surveys conducted in the most recent week, month, or all time (millenium), or by the proportion of surveys on which caterpillars were observed.

Seeing which *Site* or which *User* has the highest percent of surveys with caterpillars is mostly for bragging rights. Can you get yourself into the top 10 for surveys conducted this year? Click on any *Site* name in the table to explore the data for that site in more detail (see below).

Explore the Map
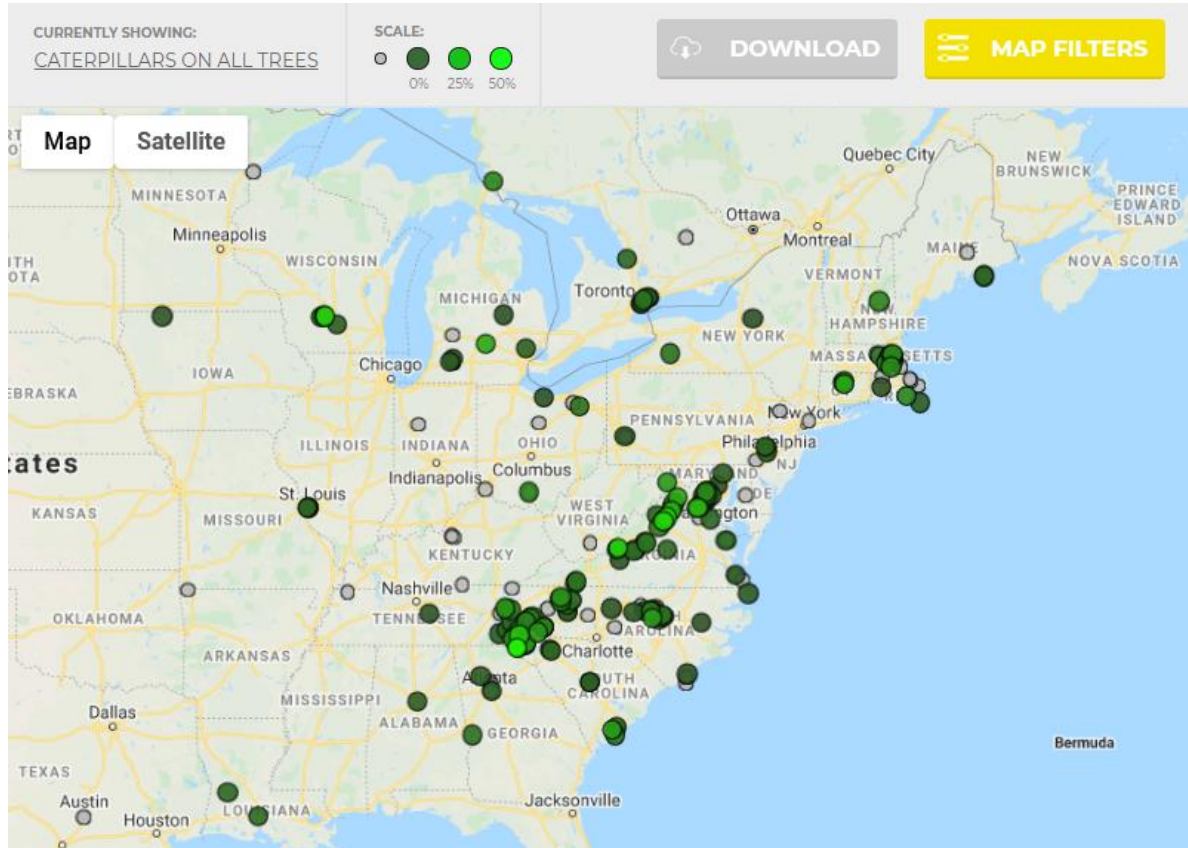
The **map** of existing *Caterpillars Count!* sites allows you to explore spatial patterns of arthropod abundance. By default, the point colors reflect the relative occurrence of caterpillars, with lighter green indiating higher values. You may customize this visualization by using the **Map Filters** button as described below.

Filter Map Data

1) Choose which **Comparison Metric** you would like to display. *Percent of Surveys* is the % of survey branches on which the specified arthropod group was found (the default), and *Number per Survey* is the average number of individuals found per survey. *Biomass per Survey* is the average estimated weight of the specified arthropod group per survey based on the reported lengths of the arthropods observed.
2) You can limit the display to data collected by a particular **Observation Method** if desired. By default, both *Visual* and *Beat Sheet* survey data are included.
3) Select the **Arthropod Group** you'd like to include in your visualization.
4) Select the M**inimum Length** in millimeters that you are interested in summarizing. For example, you might decide you only want to know about arthropods larger than 10 mm. By default, data on all sizes will be included.
5) You have the option of restricting your analysis of arthropod density or occurrence to a particular **Plant Species**. Start typing either the scientific or common name and then select the plant species of interest. By default, results will be displayed based on data from all plant species. NOTE: *If you restrict by plant species, you will quickly realize that not all tree species have been surveyed at every location!*
6) Unclick the check box if you do NOT want to include surveys conducted on **Wet Leaves**. Surveys conducted under these conditions may reflect lower insect activity than would otherwise be expected.
7) Adjust the sliders to restrict the **Month**(s) and **Year**(s) of data that you'd like to display. For example, if you only wanted to compare caterpillars seen in the month of June.
8) Click **Apply Filters**!

You Ask, You Answer!

This mapping interface provides the flexibility to investigate a wide range of scientific questions about arthropods found on woody plants. **Example questions** that could be asked:

- *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?*
- *What is the impact of wet leaves on patterns of arthropod density and occurrence?*
- *Are geographic patterns of arthropod density consistent from year to year?*
- WHAT OTHER QUESTIONS DO YOU WANT TO ASK?

Map Data Download
The data underlying the mapped values are provided by clicking on the **Download** button at the map's top right. You will get a zipped folder with two files:

data.csv has the list of sites, their coordinates, the filter settings, and the mapped values. It can be opened with Microsoft Excel or other spreadsheet or data analysis software.

metadata.txt defines what each column in *data.csv* means, and provides a recommended data citation. It can be opened by any text editor (e.g. Notepad, TextEdit), browser, or Excel.

Exploring Site Specific Data

To dive into data from a particular site, **click a location on the map** or the site name on the leaderboard. That site will now show up as a yellow dot on the map. Keep scrolling below the map and you'll find a **site description**, a **summary of site data**, and a **leaderboard for users at that site**, with survey statistics that can be sorted by column headers.

Here's an example from the **NC Botanical Garden** site in Chapel Hill, North Carolina:

NC BOTANICAL GARDEN

Survey sites are along the Streamside Trail of the North Carolina Botanical Garden.

Last surveyed 47 days ago.

SITE SUMMARY

Users	Surveys	Arthropod Groups	Arthropods	Caterpillars
31	6227	14	12960	453

USER LEADERBOARD

Visit your Settings page and click on "Privacy" to hide your name from leaderboards like these.

| | User name | SURVEYS THIS... | | | | Caterpillars |
		Week	Month	Year	Millennium	
1	Kinsey Fisher	0 0 survey date(s)	0 0 survey date(s)	429 22 survey date(s)	429 22 survey date(s)	5.83%
2	Allison Duprey	0 0 survey date(s)	0 0 survey date(s)	417 21 survey date(s)	417 21 survey date(s)	5.76%
3	Andrew Zachman	0 0 survey date(s)	0 0 survey date(s)	363 21 survey date(s)	363 21 survey date(s)	6.06%
4	Sara Snell	0 0 survey date(s)	0 0 survey date(s)	327 12 survey date(s)	438 17 survey date(s)	7.31%
5	Grace Di Cecco	0 0 survey date(s)	0 0 survey date(s)	245 12 survey date(s)	245 12 survey date(s)	4.9%
6	Allen Hurlbert	0 0 survey date(s)	0 0 survey date(s)	40 9 survey date(s)	796 54 survey date(s)	8.29%
7	Molly Jenkins	0 0 survey date(s)	0 0 survey date(s)	20 1 survey date(s)	20 1 survey date(s)	5%
8	William Larsen	0 0 survey date(s)	0 0 survey date(s)	0 0 survey date(s)	102 5 survey date(s)	1.96%

Below the site's **User Leaderboard** are buttons for the three graphing options available, each of which is explained below:

| PHENOLOGY | COMPOSITION | TRENDS |

Phenology

| PHENOLOGY | COMPOSITION | TRENDS |

Below the site summary is a graphing tool to help you visualize the **Phenology** (or seasonal variation) of the arthropods found at the site you selected. The default view plots a **line graph** showing the **Percent of Survey** branches examined on any given day at the site of interest with at least one caterpillar.

Click on the y-axis label to change the phenology metric and instead plot seasonal variation in arthropod density (**Number per Survey**) or biomass (**Biomass per Survey**).
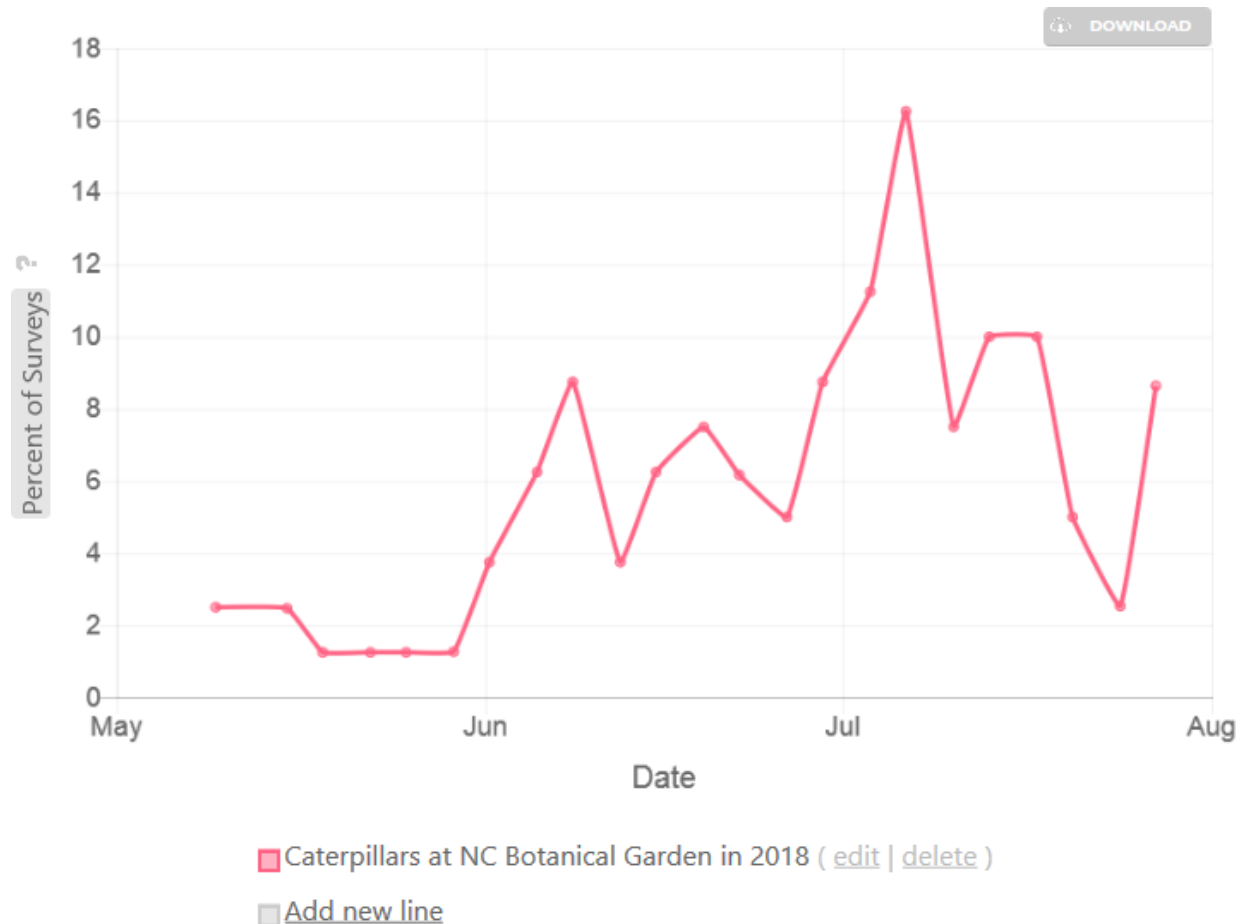
Use the **Add New Line** link at the bottom to add a new phenology curve to the graph for comparison. You will be able to select the arthropod group, the site, and the year you'd like to display by clicking on those terms. Then click **confirm**.

You can add up to 14 phenology curves to the same graph, facilitating comparisons between years, sites, or arthropod groups!

You Ask, You Answer!

**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(s) consistent between years?*
- *Is the timing of the peak(s) consistent between tree species in the same year?*
- *Is the timing of the peak(s) consistent across different sites?*
- *Why might different groups of arthropods exhibit differently timed peaks of abundance?*
- *Why might the timing of peaks be different at different sites?*
- *What environmental factors might affect patterns of arthropod abundance?*

This is a good opportunity to get students thinking about what causes these patterns of arthropod abundance.

Phenology Data Download

Click on the **Download** button at the top right to get a zipped folder with *data.csv* and *metadata.txt* files as described above.
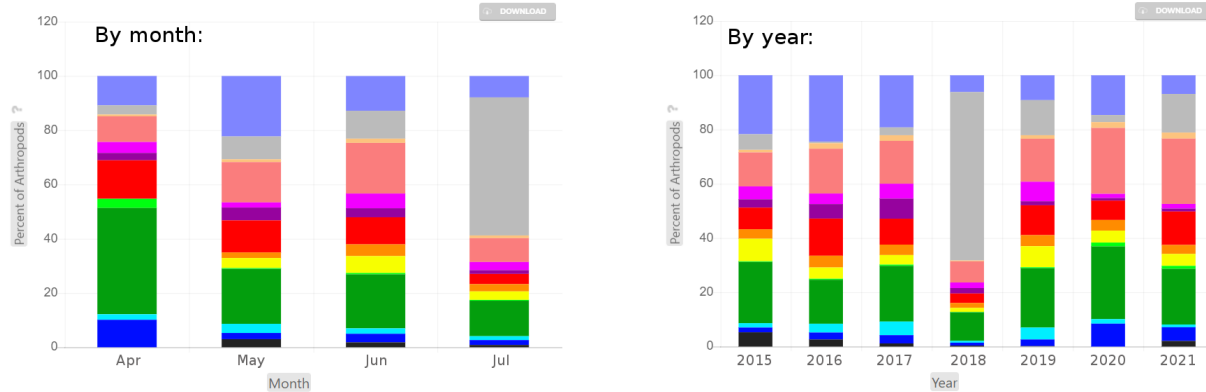
Arthropod Composition
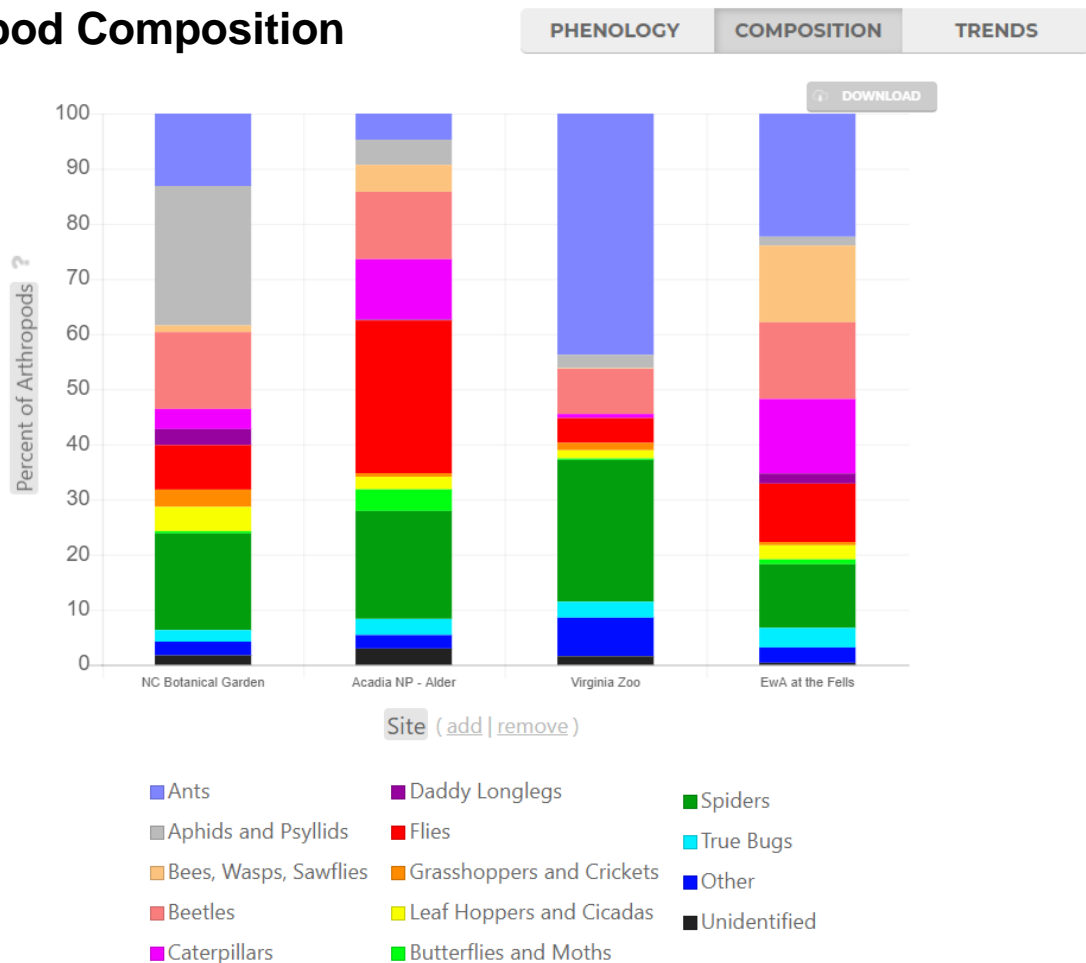
Clicking the **Composition** tab at the top of the **Graphs** panel will change the visualization to a bar graph depicting the prevalence of the different arthropod groups found at the site.

To compare arthropod composition between sites, click "add" in the x-axis label next to **Site** and select the site you liked to add. You can repeat this process to add multiple sites to your comparison as in the example above.

Instead of comparing to other sites, you can also examine how arthropod composition at your site varies from **month to month**, **year to year**, or **depending on the plant species**. For these visualizations, click on the **Site** x-axis label and change it to **Month**, **Year**, or **Plant Species**.

Note that there are **four different measures of arthropod composition** that you can visualize by clicking the y-axis label. Options include:

- **Percent of Arthropods**: The percentage of all arthropods encountered by number of individuals. Must sum to 100 across arthropod groups. (Default)
- **Percent of Surveys**: The percent of survey branches with at least one arthropod of the type specified. Need not sum to 100 across arthropod groups.
- **Number per Survey**: The total number of arthropods encountered divided by the total number of surveys, calculated for each arthropod group.
- **Biomass per Survey**: The total estimated dry weight of arthropods (based on their lengths) divided by the total number of surveys, calculated for each group.

You Ask, You Answer!

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

- *Which types of arthropods are most frequently encountered at my site?*
- *How do tree species differ in terms of the types of arthropods that are found on their leaves?*
- *Do spiders occur at some sites more frequently than at other sites?*
- *Has the relative abundance of different arthropod types changed over time at my site?*
- *What factors might influence which arthropods are more or less abundant in a given year or at a given site?*

This is another good opportunity to have students think about **why** questions, trying to connect the patterns they observe to each other or to other aspects of an ecosystem.
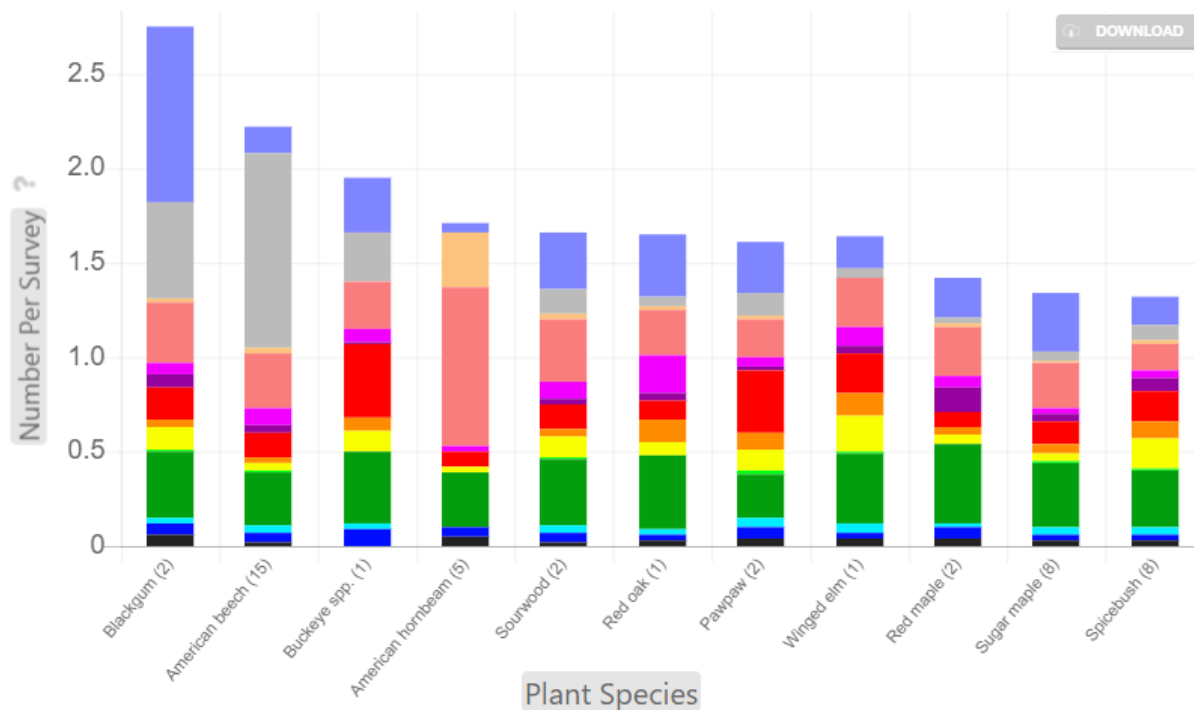
Above is an example that shows the **Number per Survey** of each arthropod type as a function of the different **plant species** surveyed at the site. Looks like American hornbeam is particularly good for beetles (pink), but not so much for caterpillars (hot pink).

Composition Data Download

Click on the **Download** button at the top right to get a zipped folder with *data.csv* and *metadata.txt* files as described above.
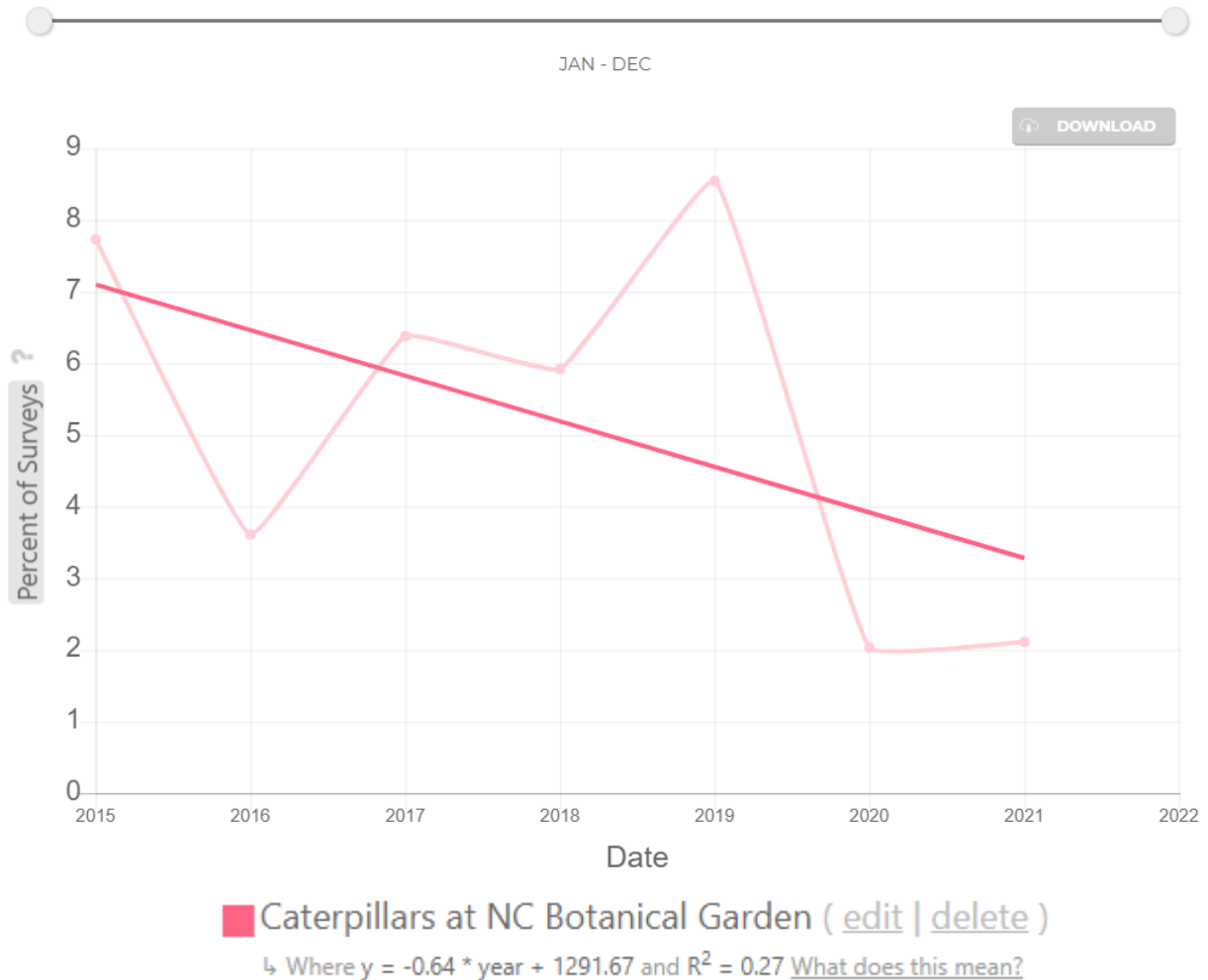
Trends

Are insects declining?! There have been several worrying reports from around the globe, but the necessary data for properly evaluating this claim are often lacking. This is one of the most important questions that *Caterpillars Count!* data can address. Assuming that data have been submitted at a site for multiple years, then the **Trends** feature allows one to see how arthropod **occurrence**, **density** or **biomass** has varied from year to year, and whether there are any indications of a long-term trend.

Check out either the NC Botanical Garden or Prairie Ridge Ecostation or Coweeta BS sites in North Carolina if you're looking to explore this **Trends** feature with a site that has built up a reasonable time series.

Caterpillars at NC Botanical Garden (edit | delete)
↳ Where y = -0.64 * year + 1291.67 and R^2 = 0.27 What does this mean?

Interpreting the trend

In the example above , a pale line connecting data points displays the **average percent of surveys with caterpillars** in each year that the site has been surveyed. The darker line is the best fit linear trend through these data. Below the graph in the legend, you will find the regression equation, in this case: **y = -0.64 * year + 1291.67**

The most important number in this equation is the **slope**, or the number being multiplied by "year". In this case, it is telling us that each year, the percent of surveys with caterpillars decreases by 0.64% on average.

The second most important number in the legend is called the **coefficient of determination**, and is abbreviated R^2 (or "R-squared"). This number describes the proportion of variation in the y-variable (here, % of surveys with caterpillars) that is explained by the x-variable (year). If the R^2 is close to 1, it implies a very tight relationship between year and % caterpillars, and when it is close to 0, it implies that there is a lot of variation from year to year that is not captured by this trend line. In this example, 27% of the variance is explained by this yearly trend, but there are lots of ups and downs as well that reflect some combination of statistical noise or unusual conditions in a particular year.

Selecting a month window

At the top of the graph you will see **a month slider** that is by default set from January to December, which indicates that all survey data are included in these yearly estimates. But perhaps you want to examine trends during a particular time of year specifically? You can drag the sliders to encompass just a subset of months, or even just a single month. It might be especially important to select a common month window if you know that the sampling season varied from year to year.

Below we see that although, the % of surveys with caterpillars has been decreasing overall, it has actually been increasing on average slightly when comparing findings in May only from one year to the next.

Caterpillars at NC Botanical Garden (edit | delete)
I, Where y = 0.25 * year − 502.51 and R^2 = 0.06 What does this mean?

Graphing options

As with the Phenology graphs, you can click on the y-axis label to visualize trends for **Number per Survey** or **Biomass per Survey** instead. You can also add multiple trend lines to the same plot to compare trends in the same arthropod group at different sites, or as is shown below, different arthropod groups at the same site. Simply click **Add New Trend** at the bottom.
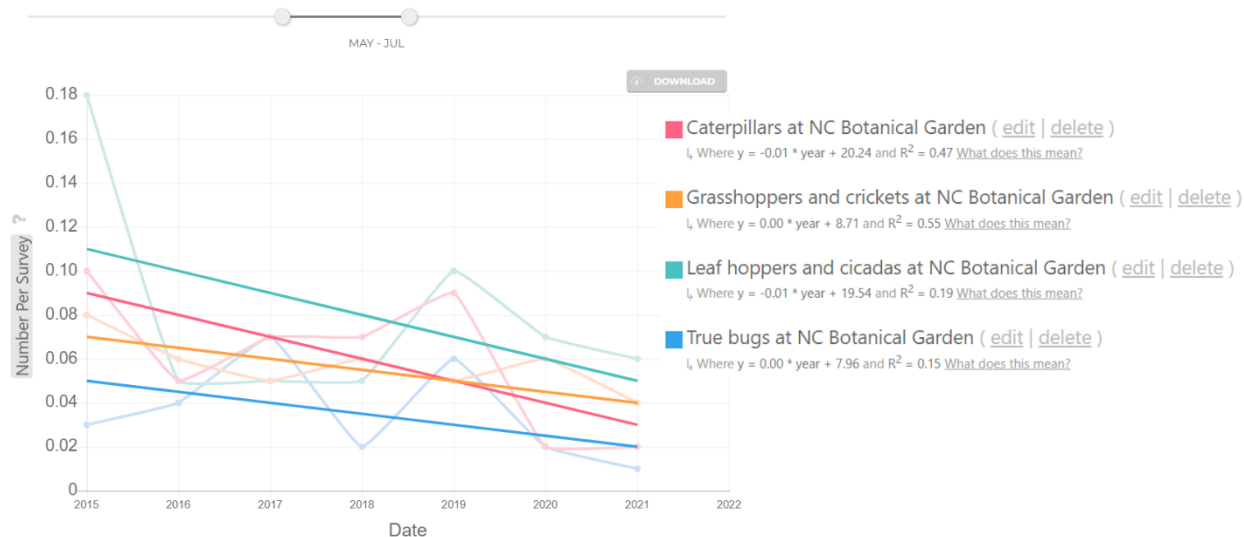
You Ask, You Answer!

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

- *Which types of arthropods show the biggest declines?*
- *How consistent are trends for a given arthropod type across sites?*
- *Where are caterpillars declining the most?*
- *Do some sites exhibit greater declines (or increases) than other sites?*
- *Are years that are good for some arthropod groups also good for other arthropod groups? That is, do the groups go up and down in sync?*

This is another good opportunity to have students think about **why** questions, trying to connect the patterns they observe to each other or to other aspects of an ecosystem.

Trend Data Download

Click on the **Download** button at the top right to get a zipped folder with *data.csv* and *metadata.txt* files as described above.

Data availability

For advanced users, all of the **raw data** from *Caterpillars Count!* can be downloaded from the Explore > Data Download page. You can filter the data to download for a particular set of years, sites, or arthropod types. Refer to the *metadata.txt* file to understand how this data is organized.

Reading these raw data into Excel or statistical programming software like *R* will allow students to **evaluate more specific hypotheses, conduct statistical tests, and develop their own graphical visualizations**. Please let us know what you find at *caterpillarscount@gmail.com*!

Background Information for Class Instructors

Many of the patterns that will emerge from these data have never been well described, so in many cases there is no "answer key". The participants that have conducted surveys for this project are contributing important data that will help us better understand how foliage arthropods vary over time, in different habitats, 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 shorter windows of seasonal activity and later peak densities of arthropods 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.
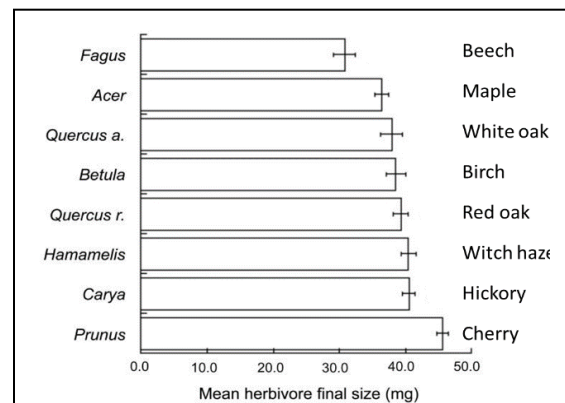
2. *Trees as food*

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.

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.

The graph at right shows an example of how different tree species differ in nutritional quality for caterpillars. The study was led 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!

Desiree Narango and Doug Tallamy have shown that in general, yards with more native plant species have more caterpillars, and birds in those yards are successful at raising more young.

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

3. *Insect declines*

Insect declines are very real. What we don't know yet is just how universal they are. Here are some well documented declines:

- Flying insects in western Germany have declined by over 75% since 1989 ([source](#)).
- Monarch butterflies populations have declined by 84% in eastern North America and 99%(!) in western North America in recent decades ([source](#) and [source](#)).
- Moth numbers from light trapping at the Rothamsted Insect Survey in the United Kingdom have declined by 31% since 1969 ([source](#)).

No question this is bad news, especially for monarchs broadly. But areas where insect populations are stable are much less likely to garner attention. Many less charismatic insect groups have not been studied at all, and even for charismatic groups, they probably have not been studied in most parts of the world.

Recently there were two concerted efforts to systematically analyze as many insect time series datasets as possible to try to assess general trends. The basic summary is that trends are highly variable between species and sites, and there are plenty of examples of increases in particular insect populations as well.

[This study](#) by van Klink and colleagues published in 2020 examined 166 long-term surveys across 1676 sites around the globe (mostly northern hemisphere). Overall they found terrestrial insects to be declining on average by ~1% per year and freshwater insects to be increasing on average by ~1% per year.

[This study](#) by Crossley and colleagues from 2021 examined thousands of insect time series from 68 sites across the United States and found increases to be equally as common as decreases, with no clear indication that particular insect groups were more threatened than others.

As *Caterpillars Count!* sites continue to accumulate monitoring data, we may be better able to assess trends in foliage arthropods across the continent than we ever have before. What patterns do you see?