**A Bug’s Life Changing a Plant’s Life: Exploring the Relationship Between Gypsy Moths and Deciduous Broadleaf Trees in Connection to Accumulated Growing Degree Days**

Imagine walking through the deciduous forests in Massachusetts early one spring. It’s warm enough to enjoy the trees full of green leaves, after they’ve spent a whole winter as leafless sticks. Surrounded by the many oak and maple trees, you’re already planning a trip back during the fall season when the forests will change from green to the orange and gold colors of autumn. Thinking of how most of Massachusetts will look in two seasons as you walk deeper into the quiet forest, you begin to hear a calming rain and start to feel raindrops falling down on you.

As you wipe the raindrops off of your face, you look down at your hand and notice that instead of water, you wiped away dirt. Taking a closer look, it seems as though the dirt is actually bits of leaves that have been chewed. Looking up into the forest canopy, you now see the thousands of hairy caterpillars that are covering the trees and realize that the rain you hear and the dirt on your face is the excrement of these caterpillars from eating the leaves of the trees you stand under. These forest pests are the larvae of the gypsy moth.

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| Deciduous broadleaf tree (from HARV since in Massachusetts) in leaves phenophase | Gypsy moth larvae |

*The Gypsy Moth*

Gypsy moth caterpillars primarily feed on the leaves of deciduous broadleaf trees, and they can be known to completely defoliate entire trees. *Lymantria dispar,* commonly known as the gypsy moth, is native to the forests of Europe and was first introduced into Massachusetts in the late 1800s. This invasive species has since spread as far west as Minnesota and as far south as North Carolina. The gypsy moth does not have many natural predators in the United States, contributing to this species’ ability to continue breeding and, ultimately, dominating where it inhabits.

As temperatures steadily increase and precipitation regimes change, deciduous broadleaf trees become more vulnerable to the damage of gypsy moth larvae. When springs are drier, gypsy moths are more abundant as the killing success of the fungus *Entomophaga maimaiga* is weakened. With the possibility of drier springs due to higher temperatures, the defoliation damage of gypsy moths is more severe.

When too many leaves are consumed, the ecohydrology and local weather in the area may be affected by the loss of the canopy. With less canopy coverage over water sources, increased algae blooms may occur due to exposure to more sunlight and increased water temperature. Algae blooms can negatively affect the whole aquatic ecosystem as other organisms in the water that need sunlight can’t get it due to the abundance of algae. This can cause a decrease in food supply for aquatic animals and can create a domino effect within the aquatic food web.

The leaves that fall from trees supply a source of carbon to the microbes in the soil that are important regulators in the carbon cycle. When the time comes for the leaves of these trees to fall, but there are no leaves due to the defoliation of the caterpillar pests, then important ecosystem cycles are affected. Likewise, small mammals, birds, and native insects that rely on these trees for food and shelter suffer from the loss of their food source and protection. With a destructed habitat, these animals’ survival is in jeopardy, and the stability of their food web is at risk.

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| Cascading effects image that Katie mentioned |

*Heat Accumulation and the Gypsy Moth*

The gypsy moth depends on the accumulation of heat to transition between life stages. Researchers track this annual accumulation of heat as accumulated growing degree days (AGDDs) calculated using daily temperature data. Growing degree days (GDDs) are the number of degrees the average daily temperature exceeds the temperature below which the organism will remain developmentally inactive, also known as the base temperature. For land managers trying to control gypsy moth infestations, the most important life stage to monitor in the gypsy moth is when eggs hatch and larvae start feeding. The timing of when eggs hatch and deciduous trees become in danger can be predicted using AGDDs.

AGDDs for gypsy moth egg hatch are calculated using a base temperature of 37.4˚F and the double sine method. The [National Phenology Network](https://www.usanpn.org/data/forecasts/Gypsy_moth) provides a gypsy moth forecast to predict when gypsy moth larvae are likely to emerge based on AGDDs. Looking at heat accumulation in relation to gypsy moth development can help us better understand the relationships between these pests and the ecosystems they impact. Plants, like deciduous broadleaf trees, are also affected by heat accumulation, and the effects can be observed through their changing phenology.

*Heat Accumulation and Plant Phenology*

Phenology is the study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life. Plant phenology is the transition of plants through phenophases, or observable stages of their life cycle that have a defined starting and ending point. Deciduous broadleaf trees have six main phenophases: breaking leaf buds, increasing leaf size, leaves, colored leaves, open flowers, and falling leaves.

AGDDs can also be used to observe how plants are changing in phenology and affecting their ecosystem. With higher temperatures and earlier springs, GDDs accumulate quicker. While gypsy moths develop more rapidly with higher temperatures, plant phenology can be negatively affected. When springs occur earlier, plants are more susceptible to freezes that can come after the beginning of false springs, especially when the plants have already started to transition to their next phenophase, leading to negative long-term effects on the plant.

Looking at how temperature is affecting deciduous broadleaf trees, especially in relation to leaf production, can help us better understand the relationship between these trees and the gypsy moth.

*NEON Data*

Comparing AGDDs and changes in plant phenology can be achieved using available plant phenology data and daily temperature data, both of which can be obtained through the NEON Data Portal. NEON has been collecting data on [plant phenology](https://data.neonscience.org/data-product-view?dpCode=DP1.10055.001) at NEON terrestrial sites across the United States since late 2013. Part of the data follows deciduous broadleaf trees as they change through their phenophases. NEON employs status-based monitoring in which the phenological condition of an individual is reported any time that individual is observed. Status and intensity data are reported per phenophase per individual or patch, for each day observed.

[Air temperature data](https://data.neonscience.org/data-product-view?dpCode=DP1.00002.001) is also collected at NEON field sites using sensor assemblies on deployed towers. With this air temperature data, AGDDs can be calculated. For observing deciduous broadleaf phenology in comparison to AGDDs, a base temperature of 50˚F and the temperature averaging method was used to calculated AGDDs throughout a calendar year.

By mapping this heat accumulation in the form of AGDDs and comparing it to the transitions in phenophases for deciduous broadleaf trees, the relation between the two can be observed. Further, by comparing across years and NEON field sites, it is possible to make predictions for changes in the climate and changes in phenology in years to come using real time data.

Explore the relationship between plant phenology and temperature in the application below, where it is possible to observe changes in deciduous broadleaf tree phenology across years at a specific field site. Examining what percentage of the observed individuals are in each of the phenophases throughout the year can give a better understanding of how these plants change from phenophase to phenophase and how these transitions may occur earlier or later from one year to the next.

In the application, it is also possible to view AGDDs as calculated for the deciduous broadleaf trees for a specific field site. By looking at each year, it is helpful in understanding when GDDs accumulate more or less depending on the time of the year. Comparing multiple years can help in understanding how AGDDs are changing over time.

By choosing to observe both phenophases and AGDDs, it is easier to compare how accumulated heat may be affecting the transition in phenophases of the deciduous broadleaf trees.

Shiny app

*Using NEON Phenology Data to Understand our Changing Ecosystems*

Examining how plant phenology changes over time, especially in relation to temperature and heat accumulation, is important in: optimizing when to plant, fertilize, and harvest crops; managing invasive species, like the gypsy moth; predicting human health-related events like the timing and severity of allergies; understanding the timing of ecosystem processes, such as carbon-cycling; and assessing the vulnerability of species and ecological communities to ongoing climate change.

The Observatory will continue to collect phenology and air temperature data for the next 30 years, making it possible to monitor ongoing patterns and make predictions for future seasonal changes. These predictions can then help us in understanding interactions throughout parts of the food web and ecosystems that may be affected by changing climates.