THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
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PHENOLOGY

USING PHENOLOGY AS A TOOL FOR EDUCATION, RESEARCH, AND UNDERSTANDING ENVIRONMENTAL CHANGE

Peter L. Warren and LoriAnne Barnett

PETER WARREN

Figure 1 Costa's hummingbird (*Calypte costae*)

PETER WARREN

Figure 2 Saguaro in bloom (*Carnegiea gigantea*)

Phenology is the study of recurring plant and animal lifecycle stages, or phenophases, their timing, and relationship to the environment. Phenology is sometimes called the "science of the seasons" because the different phenophases we observe such as blooming plants and migrating birds are seasonal events. In short, phenology can help us understand ecosystems and species interactions for healthy environments.

Examples of phenology include: Costa's hummingbirds, a common migratory species in the southwest, breed in the Sonoran and Mohave Deserts after migrating from southern California and west-central Mexico where they spend the winters (Figure 1). Pollinators arriving at just the right time support the reproduction and propagation of Sonoran Desert species, such as the white–winged dove and lesser long-nosed bats that visit the saguaros in the spring after returning from migration. Their visits to the cacti when the flowers are in bloom (Figure 2) ensure the development of saguaro fruits in the early summer just before the monsoon season arrives. These fruits have been harvested for centuries by cultures that used them as a food resource.

Throughout history many traditional cultures, agriculturists, famous naturalists, scientists, and communities used phenology as part of decision-making in their daily lives. From understanding planting and harvesting schedules to creating written records of annual environmental events, having this information was critical to survival.

Phenophases and phenological events (Figure 3) are easy to observe. Recording these observations is now valuable to research and decision-making on a variety of topics, in much the same way this information has been for generations. Organizations such as the USA National Phenology Network (USA-NPN) (www.usanpn.org) are working to create a long-term, standardized database for storing these phenology observations; these data can then be used in climate change research as well as natural resource and policy decision-making.

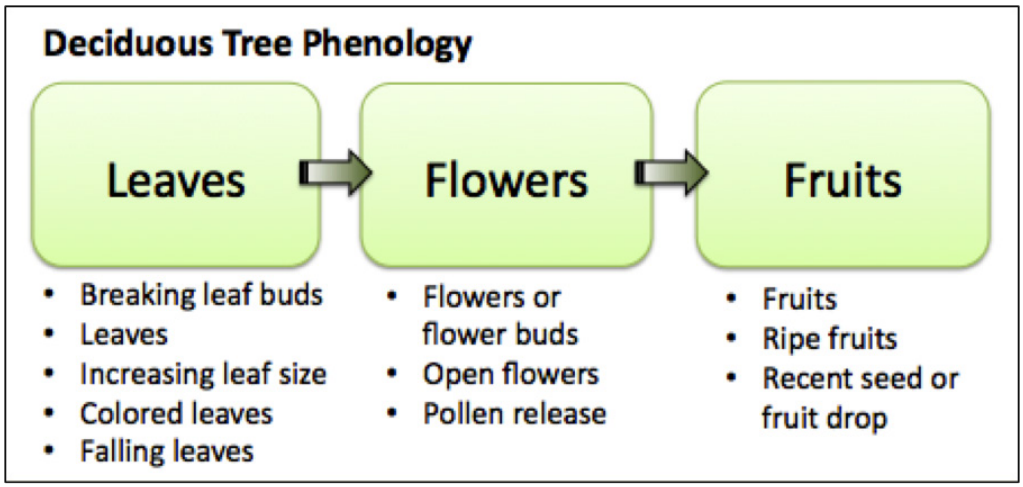

Figure 3 Seasonal phenophases of plants

Phenological patterns are important economically and biologically and are sensitive to climate change. The National Climate Assessment of 2014 reports that "forest disturbances caused by insects and pathogens are altered by climate changes due to factors such as increased tree stress, shifting phenology, and altered insect and pathogen lifecycles."[1] The US Environmental Protection Agency states, "because of their close connection with climate, the timing of phenological events can be used as an indicator of the sensitivity of ecological processes to climate change."[2] The Intergovernmental Panel on Climate Change (IPCC) states phenology is "the simplest process in which to track changes in the ecology of species in response to climate change."[3]

In addition to broad climate change research, there are a number of practical phenology applications for land management and garden environments. Phenology is used to understand pest management best practices, landscape plant management, plant propagation, vegetable and fruit tree maintenance, to create bloom calendars, and much more.

Keeping track of the phenology of various species of plants and animals can be helpful in pest management. Having records of emergence along with degree-day information can help predict when pest insects and beneficial insects will likely appear on plants. The timing of pesticide applications can be made more effective with these data and consequently save the cost of extra treatments when timed correctly. In addition, it can save our native pollinators by reducing pesticide use. For example, in apple orchards spray schedules are determined by setting out pheromone traps to determine when adult moths are flying. Using this information along with degree-day data and an understanding of the pest lifecycle, it is possible to determine when the young larvae, the most susceptible phenophase of the insect, are active and thus when to spray.

Understanding phenophases enhances management of landscape and edible plants such as vegetables and fruit trees. Proper timing of fertilizing, seasonally modifying irrigation schedules, and pruning are examples of practices that can be made more efficient with regular monitoring.

Demonstration gardens maintained by Cooperative Extension Master Gardener volunteers and school gardens maintained by students and teachers are places where people can learn the practice of tracking and recording phenological data. As a long term, multi-year project goal, consider creating a calendar to show what is blooming each week, or what insects or birds are appearing, so others can learn from the information being recorded.

Information collected can be used to meet a variety of science and math standards in the classroom such as observation, evidence gathering, ecological systems, graphing, and comparisons.

The USA-NPN hosts a professional and citizen science project called *Nature's Notebook* for storing, extracting, and analyzing phenology observations. Participating in a long-term citizen science project like *Nature's Notebook* is a good way to introduce youth and adults to the scientific process of observation, record keeping, and data analysis (Figure 4). The long-term nature of the program mirrors the rigor of well-designed scientific studies. The skills acquired can also give citizen scientists a better appreciation of the natural world around them. Participants can engage in the whole process of investigation by creating science questions to answer, gathering observations, performing data entry, analyzing what they found, and generating comparisons to what others are finding.

Extension Agents in Agriculture and Natural Resources and 4-H Youth Development can also use a project like *Nature's Notebook* to answer scientific research and management questions related to phenology, engage youth in STEM (Science, Technology, Engineering and Math) activities, though programmatically implementing a monitoring project in their

[1] From the US EPA website: http://www.epa.gov/climatechange/science/indicators/society-eco/leaf-bloom-dates.html retrieved on April 25, 2014

[2] From Climate Change 2007: Working Group II: Impacts, Vulnerability and Assessment. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch1s1-3-5-1.html Retrieved on 4/16/2014.

[3] From Climate Change 2007: Working Group II: Impacts, Vulnerability and Assessment. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch1s1-3-5-1.html Retrieved on 4/16/2014.

SARA SCHAFFER

Figure 4 Master Gardener volunteers collect phenology observations

BRIAN POWELL

Figure 5. Using phenology to teach youth.

county. Designing such a program, using a logic model, can help achieve multiple outcomes and impacts (Figure 5).

For example, a long-term *Nature's Notebook* project, in Pima County, Arizona, was implemented by the Urban Horticulture Agent to achieve t**raining, outreach**, and **research** goals for the Urban Horticulture program.

1.) Phenology was added as a topical area to the Master Gardener **training** course to demonstrate that many gardening activities are based upon phenology to make predictions and understand best practices.

2.) The Master Gardeners were required to collect weekly phenology observations in the local demonstration garden for class credit. They were also given guidelines on how to create scientific hypotheses and encouraged to collect evidence to support them as well as report out on some preliminary findings by the end of the course.

3.) The plants in the demonstration garden tagged for the *Nature's Notebook* monitoring project are species of interest for **local research projects**, including pest management (to make recommendations via the plant clinic) and mesquite bean harvesting. Having a phenology dataset available to make recommendations to the public meets **outreach** goals. Having a consistent group of people collecting data (e.g. the Master Gardener class participants, Extension Agents, and other volunteers) ensures the creation of such a dataset.

4.) The monitoring project provides opportunities for Master Gardeners to interact with other Extension program areas (e.g. 4-H – phenology stations at garden field days), as well as the community via phenology garden tours.

5.) The Master Gardener course materials are evaluated and updated for efficacy each semester, the content is used in **educational research**, and materials are distributed nationwide.

6.) Ultimately the data gathered is contributed to the National Phenology Database in support of **national and international climate change research.**

For more information on phenology as a teaching and research tool or how to participate in *Nature's Notebook*, visit **www.nn.usanpn.org**. Email **education@usanpn.org** for more details.

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THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721

PETER WARREN
Associate Agent, Urban Horticulture

LORIANNE BARNETT
Education Coordinator, USA National Phenology Network

CONTACT:
PETER WARREN
plwarren@cals.arizona.edu

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