Sandhill cranes are arriving two weeks earlier at the Sherburne National Wildlife Refuge in Zimmer, Minnesota.

Local Phenology Tracks Climate Change

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One non-controversial way to teach climate change is through phenology, the observation and recording of the timing of life-cycle events for plants and animals. The word *phenology* has its roots in the Greek words *phaino* (to show) and *logos* (to study). Charles Morren coined the word in western science in 1848, as the study of seasonal changes in life cycles of plants and animals. These changes include when robins return and cherry trees bloom in spring, when fruits are ripe in the summer, and when deciduous leaves senescence in the fall.

Many communities have for millennia, and still do, use phenology to support their livelihoods. For example, the 13-moon calendar of the Anishinaabeg describes phenological events, maple moon, strawberry moon, wild rice moon, etc. European calendars from the 1600s depict seasonal events such as planting, shearing sheep, harvesting etc. The longest written record of phenology began in 850 AD in Japan. It records the time of the peak of cherry blossoms, which is used as a festival that marks the beginning of a new season.

The timing of life cycle events is critical in ecological systems and food webs. Insects emerge when leaves and flowers are available as a food source, birds arrive when insects emerge. Phenological mismatches, or asynchronous life-cycles of species dependent upon each other, can result in plants not being pollinated or birds not having a food source for their young. Not only does phenology data document climate change, it also helps improve understanding of growing season lengths, pest outbreaks in forests and crops, pollinator services with plants, and critical allergy season lengths. Resource managers use the phenological information to inform when to mow invasive species, plant new species of trees, or street sweep fallen leaves. Even companies like Macy's use phenology to know when to run their spring sales based on certain blooming flowers. We are all

connected to phenology even if we have never heard the word before.

Documenting phenology over multiple years helps us see both change and stability in ecological communities. Many naturalists do this important work by collecting daily records at their local parks, camps, nature centers, scientific areas, etc., across the world. They use interpretive techniques designed to connect humans to these life cycle events through storytelling and active learning. For example, we can create questions which observational data can answer, including whether plant bloom time is shorter or migrating birds return earlier each year. In turn, this data supports the hypothesis that climate change can be observed locally.

We have all heard statements like, "The Canadian shad fish run up stream when the Juneberry blooms" or "Plant your corn when the oak leaf is the size of a squirrel's ear." These are phenological events that have guided human behavior for millennia. Skilled naturalists capitalize on these dynamic systems-based observations to provoke people to think deeply about their own experience with nature's calendar and connect them to science-based concepts like climate change. Keeping personal records on the timing of phenological events allows individuals to see in real time the differences between seasonal and long-term ecosystem changes.

We have scientific support that climatic change is happening all around us. Our summers are hotter and drier, and winters are warmer and shorter. Our home state, Minnesota, is at the confluence of three major biomes. In the next 50 years, scientists predict that one of these biomes—the boreal forest—will move to the northeast and our summer climate will be closer to that of Nebraska, two states to the south. Relating this information to community members and eliciting their experiences inspires them to record what they see.

In Minnesota, over the last decade a concerted effort has been made to collect historical phenological data, digitizing, analyzing, and charting the results and making it available to scientists, naturalists, teachers, and the public through the Minnesota Phenological Network's website (mnpn.usanpn.org). In addition, recruiting people to collect data using a standardized method such as Nature's Notebook (naturesnotebook.org) has increased Minnesota's phenological records tenfold.

What have we learned from naturalist/scientist historical data collected over the last half century? Alec Hodson, a University of Minnesota entomology professor, recorded phenology of aspen as he walked to and from school every day. His data from 1940s to 1990s, coupled with current data, have shown after 80 years these trees are breaking bud two weeks earlier in the spring. This matches the climate trend and helps to demonstrate the relationship between temperature and bud break. Other records show that foliage coloration is lasting longer in the fall.

From other such records, we know that the sandhill cranes (*Antigone canadensis*) and eastern tailed-blue butterflies (*Cupido comyntas*) are arriving/emerging earlier each spring. Also documented is the earlier flowering period for the Carolina puccoon (*Lithospermum caroliniense*) and Minnesota dwarf trout lily (*Erythronium propullans*). Furthermore, the duration of flowering has changed, becoming shorter in Carolina puccoon and longer in the trout lily.

The yellow-rumped warbler (*Setophaga coronata*) now arrives earlier while the Baltimore oriole (*Icterus galbula*) returns around the same time each year. The oriole winters in Central and South America whereas the yellow-rumped warbler winters in the southern United States. This suggests that the timing of migration may be guided by temperature for the warbler and length of day for the oriole.

While some plants seem to be breaking bud earlier, the red maple is not changing. This may have to do with starch in the buds that prevent them from breaking prematurely in an early spring thaw. Collectively from the Minnesota data, we have learned that species and phenophases differ in their degree and rate of response. In general, plants exhibit earlier budbreak and flowering and stay green longer into the fall.

Eastern tailed-blue butterfly is emerging two weeks earlier in north central Minnesota.

Naturalist 2.0

A naturalist who is a phenologist writes their observations down so the information can be used later to demonstrate ecological change over time. Larry Weber, an educator and phenologist who lives near Duluth, has recorded his plant and animal observations in a daily journal for the last 47 years. His journal (pictured), as of June 3, 2020, now has over 16,590 pages, one for each day. From the 1950s to the 1990s, the Eloise Butler Flower Garden in Minneapolis used 3x5 index cards to record phenology of many plants along its public trails. A mail carrier from Grand Rapids, Minnesota, John Latimer, has recorded plant and animal phenology observations on his 100-mile mail route for more than 25 years. He shares his observations weekly on KAXE Radio's "Phenology Talkback" show to which schoolchildren across the state also contribute their observations.

There are a number of ways to get started with recording basic phenology observations using online citizen science programs such as iNaturalist (inaturalist.org), Frog Watch, USA (aza.org/frogwatch), BudBurst (budburst.org), Monarch Watch (monarchwatch.org), and Journey North (journeynorth.org). All of these programs support the public participation in the collection of scientific data, which is important because scientists and researchers on their own cannot collect enough observations to tell a complete story about the changing of the timing of these events through the years.

Nature's Notebook, a program

of the USA-National Phenological Network, is another phenology observation program used across North America to document site-based long-term changes in phenology. Nature's Notebook has a published set of protocols designed to help document ecological changes in your local community. The University of Arizona is home to the 11-year-old program and the data are used by scientists throughout the world.

Slightly more complicated than the other one-time phenology observation projects, Nature's Notebook requires following the same plants (trees or patch of flowers) or animal species at a given site throughout multiple years, recording more often during phenologically active times. The protocols capture status, event, and abundance records on multiple plant phenophases including breaking bud, flowering, dropping seeds or changing leaf color. Animal phenophases that can be reported include nest building, feeding, raising young, and migration. If you are unsure of what you are seeing there are training materials to help with phenophase identification. Nature's Notebook has a mobile app that makes it easy to use in the field and includes the phenophase information. All of the data are freely available to anyone and can be downloaded for analysis.

Nature's Notebook has over 14,000 active sites and 380 Local Phenology Programs managing long-term data collection. Many parks have established "phenology walks," or trails with plants marked for observation, to which the public can contribute observations. There are a number of campaigns designed to answer specific science questions to which you can contribute (usanpn.org/nn/campaigns). It is easy to create an observation site in your backyard.

Naturalists can become Local Phenology Leaders by attending an online certification course through the USA-NPN. This training provides a new skill set and supports lifelong learning for staff and volunteers like Master Naturalists. It is designed to teach participants how to create, maintain, manage, and evaluate a long-term phenology program at a public site. Becoming a phenologist or Local Phenology Leader is an ever-growing experience as your knowledge increases with each new species you discover and follow.

Plants and animals do tell the stories that can help us better understand what is happening in these ecological communities. Recording phenology in Nature's Notebook can answer not only your own local climate change questions but contribute to larger universal questions around ecological processes such as stability and change.

ABOUT THE AUTHOR

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