# Phenology, citizen science, and Dave Bertelsen

## 25 years of plant blooms on the Finger Rock Trail in the Santa Catalina Mountains

By Zack Guido

Dave Bertelsen carefully placed his foot on a slab of water-polished granite made slicker by overnight monsoon rains. Hiking to a perch that overlooks the Finger Rock Canyon arroyo, now rushing with coffee-colored water, he pointed to three seemingly ordinary clumps of grass. To Bertelsen, they are weeping muhly, a rare species found in the Southwest and seen only in five locations in Arizona to date. Bertelsen discovered these on one of his 1,180 round-trip hikes on the craggy Finger Rock Trail that scrambles five miles up to the summit of Mount Kimball in the Santa Catalina Mountains north of Tucson, Arizona.

Bertelsen is a self-trained botanist with perhaps the most in depth knowledge of flora in the Catalina Mountains, one of Arizona's sky islands. When it comes to the plants and animals in a 30-foot vicinity of the Finger Rock Trail, there is no question he is the world's foremost expert: he can identify 596 different plants species around the trail. Since 1983, Bertelsen has been hiking the rugged trail, logging more than 12,000 miles. On each trip, he meticulously records which plant species are in bloom.

He started recording blooming dates "out of curiosity," he said.

To scientists at The University of Arizona and at the National Phenology Network (NPN) in Tucson, Bertelsen's efforts are vital to documenting changes in the timing of life cycle events, such as first flowering date, and to observing landscape changes stemming from climate change. But to Bertelsen, the pursuit of science is trumped by his affection for the desert and particularly the Finger Rock Canyon. "I love the canyon. The diversity of flowers is astounding," Bertelsen said. "Each hike is exciting. Each time I see something new. This canyon contains more than 40 percent of the plant diversity found in the entire Catalina Mountains."

Bertelsen crouched on the granite slab with his back to the weeping muhley grass and pointed to sprouting seedlings. Although he's hesitant to identify them before they flower, Bertelsen recognizes them as smallflower halfchaff sedge. "I've only seen this plant at this location on the mountain," he said.

He then proceeded to recant the story of John Lemmon—locals named Mount Lemmon after his wife Sara. In 1881, Bertelsen said, John Lemmon and Cyrus Pringle were the first to collect *Anoda reticulata*. It was again collected in 1939 and 1940 west of Nogales. It hasn't been seen since in Arizona until Bertlesen discovered it on this trail in 2007.

Bertelsen continues with the history lesson but stops midsentence. "Oh, wow!" he said. "I haven't seen that since 2002." He squinted, visually prying apart a canopy of desert scrub and pointed to a hint of yellow. "That's Hooker's evening primrose. It's a night bloomer that is pollinated by the sphinx moth."

It's amazing that the scientific value of Bertelsen's knowledge was only recently recognized. In fact, several botanists told him that he was wasting his time. One called him the last of the 19th century botanists, a reference to people who collected plants without a purpose.

Bertelsen, however, did have a purpose. His strategic plan from the get-go included dividing the trail into five segments so that he could track the flowering of plant species at different elevations and determine the composition of vegetative communities. Mike Crimmins, a climate science extension specialist for the UA who is involved in many outreach and community science projects, immediately saw the value of Bertelsen's observations. Upon meeting Bertelsen in 2005, Crimmins learned that he had amassed a continuous 20-year record of first blooming dates for hundreds of plants that spanned more than 4,000 vertical feet and many ecosystems. In 20 years, he cataloged 110,012 observations.


**Figure 1.** Dave Bertelsen at the Finger Rock trailhead in Tucson.

"I nearly fell out of my chair," Crimmins said, adding that Bertelsen unknowingly created the world's first long-term record of phenology—the study of the timing of life cycle events in plants and animals—that spans a large change in elevation. On top of that, he compiled the record with a level of detail that created a rich dataset; much remains to be learned from his work, Crimmins said.

### Phenology

One purpose of phenology is to determine how plants and animals respond to climate change, said Jake Weltzin, executive director of the recently-created National Phenology Network (NPN), which is headquartered in Tucson. What happens when nectar-producing trees

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in the Northeast bloom 25 days earlier? Phenologists have answers. In the Northeast honey bees have switched their source of nectar from the tulip poplar tree to black locust tree, causing numbers of the tulip poplar to crash. Phenologists call these observations trophic mismatches and they occur when important life cycle events in plants and animals that depend on each other no longer coincide, largely the result of climate change.

Phenological changes also affect humans. The date flowers bloom, for example, is tied to allergens and infectious diseases.

Despite the consequences of phenological changes, few long records exist in the West. The most extensive and continuous record only spans 37 years. It began in 1956, when Joseph Caprio, professor at Montana State University, recruited a network of volunteers to record changes of the purple common lilac. At the height of citizen involvement, Caprio trained 2,500 people who each noted observations about lilac development and its relation to climate.

This all ended in 1993 when Caprio retired. Continuous observations of plants were then mainly left up to PhD candidates with short-lived research projects and curious citizen scientists like Dave Bertelsen. In 2004, several scientists including Mark Schwartz of the University of Wisconsin and Julio Betancourt at the U.S. Geological Survey helped create the NPN that would revitalize Caprio's lilac network and broaden phenological observations to other species.

In that dormant period preceding the creation of the NPN, phenological records collected by citizens had no outlet. Weltzin believes that many records may be collecting dust in boxes in attics.

"The number of these 'shoebox' datasets is phenomenal," says Weltzin. Since 2004, 100 datasets that range from a couple of years to several decades have made their way into NPN's database, he said.

**Figure 2.** A northern view of Finger Rock Canyon near the trail head.

NPN was created not only to find phenology records but also to encourage citizen involvement in phenological research and to provide opportunities for interested people to contribute to science. Currently, 800 observers are involved in NPN.

In fact, encouragement by two botanists proved to be the stimulus needed to publish Bertelsen's research. "Recognition of the value of the data from professionals was very important," said Bertelsen.

**Citizen Science**

Involving citizens in research is a way to engage them in the grand challenges society is facing, like global warming. It enables thousands of additional eyes to help monitor environmental changes—critical for understanding complex interactions between climate and biology—without tapping into limited scientific funds.

Bertelsen alone may have collected $1 million dollars worth of data, says Crimmins.

"If there is anytime in history when people need to pay attention it is now, because the landscape is changing so rapidly," Crimmins said.

Phenology is not the only discipline employing the help of citizens. Rainlog, for example, relies on hundreds of participants in the Southwest. Each day volunteers measure the amount of rain in a small container located on their property and report it online. This project has given scientists and citizens a closer look at rainfall patterns for two years. Scientists are crunching the data and results will likely reveal rainfall totals in neighborhoods in Tucson, Phoenix, and other participating areas that receive more monsoon rain than others.

For Crimmins, using citizens in scientific research is mutually beneficial. It helps improve the science literacy of the participants and gives scientists real data to analyze.

"In the past 10 years, science has been enamored with computer modeling which fills data gaps by creating data," Crimmins said. With projects like NPN and Rainlog, he said, thousands of people are monitoring nature and filling in

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those gaps with data from observations instead of numeric models.

"Imagine a network of people monitoring buffelgrass in their backyard," Weltzin said, referring to an invasive species that causes considerable ecological damage in the Southwest. When buffelgrass turns green—the phenological indicator that reveals that the grass can be effectively treated with herbicides—people could submit that information on-line and a computer would generate a map. Managers would then know where to spray, Weltzin said.

**Changes in Finger Rock Canyon**

Back on Finger Rock Trail, Bertelsen pointed to a shindagger, then a fairy duster, a sacred thornapple, and a longflower tubetongue. A Gila monster used to live over there, he said pointing at a rock.

Bertelsen pulled his hand lens from his pocket and held it over a tiny flower. He then resumed his slow walking pace, scanning 30 feet side-to-side. On each hike he surveys 1.6 million square feet, an area the size of 28 football fields, marking on his checklist which plants are in bloom. This data eventually is transferred to a computer spreadsheet.

Bertelsen is 65 years old and fit. His eyes are inset and his skin is tan—hints that he spends life outside observing the landscape. Although he's adept at spotting blooms from a distance and the plants are as familiar to him as friends, each hike is time-consuming and hard. Most guide books describe the trail as strenuous, a reputation won because of the relentless grade, numerous switchbacks, and rocky, ankle-twisting sections. Bertelsen starts at midnight and finishes no less than 12 hours later. Nothing has thwarted his dedication. Not a spiral fracture to his leg that occurred on the Finger Rock Trail and required a helicopter evacuation. Not a serious arm fracture that occurred soon after his leg accident. Not even triple by-pass heart surgery at the end of his accident-prone year.

"Curiosity is a cruel master," he said with a smile.

Bertelsen's observations of more than 20 years have revealed important dynamics between the ecology and the changing climate. With the help of Theresa Crimmins, senior research specialist for the Office of Arid Lands Studies at the UA, and Mike Crimmins, an analysis of Bertelsen's work was published early this year in the peer-reviewed journal *International Journal of Biometeorology*.

The results suggest that plants lower on the trail respond more to precipitation changes while plants high on the mountain are influenced more by temperature.

The analysis also reveals that plant habitats are moving. After logging 596 different plants dotted over 4,000 vertical feet, Bertelsen has witnessed habitat shifts, expansions, and contractions. The most visible change in species location is that currently more than 15 percent of the species bloom at elevations as much as 1,000 feet higher than in the past. As a result, the top of the mountain is becoming more diverse.

Bertelsen hypothesizes that a rise in the temperature has caused plants to move uphill to remain in the same temperature. But plants can climb the mountain only so far before they run out of earth; this is likely one cause of species contraction.

Bertelsen has also witnessed dramatic changes as a result of drought. He first started noticing effects of drought in 2002, a few years after the ongoing drought began, with the demise of 35 parched saguaros in the initial two miles of the trail where precipitation is the lowest. Between 2002 and 2007, Bertelsen tallied 88 deaths—more than in the 18 years that preceded 2002.

Higher up on the mountain in the pine forest ecosystem, 42 mature ponderosa pine trees died from 2002 to 2007, and 31 succumbed in 2002 alone. Similar to saguaros, more ponderosas died in this five-year period than in the previous 18 years combined.

Changes from drought are seen in every ecosystem in the canyon, and not just with plants. Recently, Bertelsen has been hearing less cactus wrens, curve-billed thrashers, and Gila woodpeckers, the three most common birds in the area. Since 2002, he has noted a marked decrease in the number and diversity of other animals observed in the study area.

Although the majority of plants have suffered from the drought, a few have thrived. The Mojave, spineless, and plains prickly pears, and the tanglehead grass are the only native plant species to expand since the drought began.

**No Stopping**

It is fair to say that Bertelsen has spent more time in Finger Rock Canyon than anyone else. And although his efforts were driven more for the love of nature than for science, his work couldn't have come at a better time. With citizens, policy makers, and scientists increasingly concerned about the effects of global warming, Bertelsen's 25 years on the trail add vital knowledge about the biosphere-atmosphere relationship.

Bertelsen believes he is seeing accelerating change in the landscape in recent years. He suggests that if the drought and increases in temperature both continue, then he will likely witness the Sonoran Desert move uphill in the lower elevations and a loss of the ponderosa pine ecosystem in the higher elevations.

When asked when he intended to stop, Bertelsen, in disbelief that the question was asked, responded:

"I have no plans to stop."