Keeping pace with warming—can plants and animals move fast enough

By Zack Guido

The Southwest Climate Outlook first discussed changes in dates of first blooms in the Catalina Mountains in southern Arizona with Dave Bertelsen in the August 2009 issue. This article updates the observations during the last two years in Finger Rock Canyon and looks at the possible effects of rapid climate change on plants and animals.

Once a week Dave Bertelsen wakes up before most people go to bed, grabs his headlamp, and begins a 12-hour journey up and down the rugged Finger Rock Canyon trail near Tucson, Arizona. He's been doing this since 1981, and in that time he has logged 1,274 round trips, hiked more than 12,700 miles, and been air-lifted to a hospital two times.

The effort and pain has purpose. His systematic and meticulous observations of animals and blooming plants along the trail reveal rapid changes, particularly in recent years. Shifts in blooming locations of many plants, declines in the diversity of plants and animals, flowering booms and busts, and thriving heat-loving cacti all suggest that the flora and fauna profoundly feel the changes in the climate.

But can they adjust to the changes fast enough? Recent research suggests that the rate of warming will outpace the speed at which some species can migrate, essentially exposing them to new climates for which they have not evolved. In the Finger Rock Canyon, Bertelsen is witnessing seasonal snapshots of the effects of unfamiliar climes, and the hot and dry 2009 monsoon season and parched early winter months may be a window into the future of the ecosystem.

Flowering changes in the Catalina Mountains

Bertelsen is a self-trained naturalist with perhaps the most in-depth knowledge in the world of plants in the Catalina Mountains. Within a distance of 30 feet from the trail—which ascends five miles and more than 4,000 vertical feet to the summit of Mount Kimball—he can identify 600 different kinds of plants.

The claret-cup hedgehog blooms in the Finger Rock Canyon between April and July. Since 2002, nearly all the large claret-cup hedgehog clusters with 50 or more stems have died. Photo courtesy of Dave Bertelsen.

By the end of 2009, Bertelsen had cataloged 131,369 observations of flowering species and noted 63,800 observations of animals, including birds, frogs, and snakes.

Subtle changes often don't elude Bertelsen. He began counting individual amphibians and reptiles in 1996 when he noticed a drop in their numbers. He also has witnessed a decrease in diversity of both animals and plants, particularly at lower elevations. On his treks between 1984 and 1987, Bertelsen saw on average 7.5 animal species per mile. That number dropped to 4.3 species per mile between 2007 and 2009, a 42 percent decline. The number of flowering plants per mile between those same periods also fell by about 19 percent.

Another change in Finger Rock Canyon has been that more plant species are blooming at higher elevations in recent years. While Bertelsen is not tracking the movement of species specifically, changes in the elevation range of flowering plants are a good indication that plants are on the move. His observations have revealed that more than 15 percent of the species bloom at elevations as much as 1,000 feet higher than in the early 1980s. He's also witnessed contractions, expansions, and nearly every other kind of range shift possible (Figure 1).

But species also are not moving and not blooming earlier in the year, which is contrary to what many scientists expect with increasing temperatures. Only 25 percent of the 363 species between 1984 and 2003, or about 90 species, exhibited a significant change in their upper or lower limits, or both, according to a peer-reviewed article published in Global Change Biology in 2009. These observations concern Bertelsen.

"Most of the plants species show no signs of moving; they seem not to be adapting," he said. Also "only 25 species, or about 10 percent of the diversity, have changed their blooming time, and 19 of them are blooming later and not earlier." If plants bloom later, Bertelsen said, their growing season is shorter because plants cannot withstand the summer heat. This may affect seed production and throw out of whack the synchronicity between flowering and pollinators.

While temperatures in the region have trended upward during the period of Bertelsen's observations, it is possible that the temperature threshold of many species in the Finger Rock Canyon has yet to be crossed. Or, for most plant species, it takes

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longer to migrate than can be discerned from Bertelsen's blooming observations.

Can plants and animals keep pace with climate change?

Conventional ecological wisdom says that as the climate warms, the plants and animals intolerant to the new temperature will seek higher elevations with cooler temperatures. There is solid evidence for this. In the Southwest along the Colorado River corridor, for example, most plant species currently inhabit landscapes 2,300-3,000 feet higher than they did during the colder period of the last glaciation. This implies that the most threatened ecosystems in the Southwest are those in the peaks of the sky islands—mountain islands of forests isolated by intervening valleys of grassland or desert—which have limited vertical real estate above them.

The survival of a particular species, however, also depends on its ability to move at the same rate as climate change. This has been observed in the past, when some trees species in North America and Europe migrated north at about 0.6 miles per year to keep pace with gradual warming that followed the height of the last glaciation about 20,000 years ago. Similarly, fossil records from 228 animal species unearthed in the United States showed that animals migrated predominantly to the northwest and southwest an average of 730 miles, roughly the distance from Salt Lake City to Tucson, as the climate warmed following the peak of the last glaciation. From about 10,000 years ago to present 303 animal species moved predominantly to the northwest an average of about 850 miles.

The context then, however, was different than it is today. In the past 40 years, global temperatures have soared by about 1 degree Fahrenheit, and it is difficult to pluck from the past the response of plants and animals to rapid climate changes.

Will climate change outpace the speed at which plants and animals move? A peer-edited article appearing in a December 2009 issue of Nature analyzed the travel speeds necessary to maintain a constant temperature. To do this, the authors assimilated moderate warming projections produced from global climate models used in the 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report and digital elevation data that mimics Earth's topography.

Essentially, in the context of global warming, the distance a species has to travel to maintain a constant temperature depends on topography. In a slightly sloping region similar to western Kansas or Nebraska,

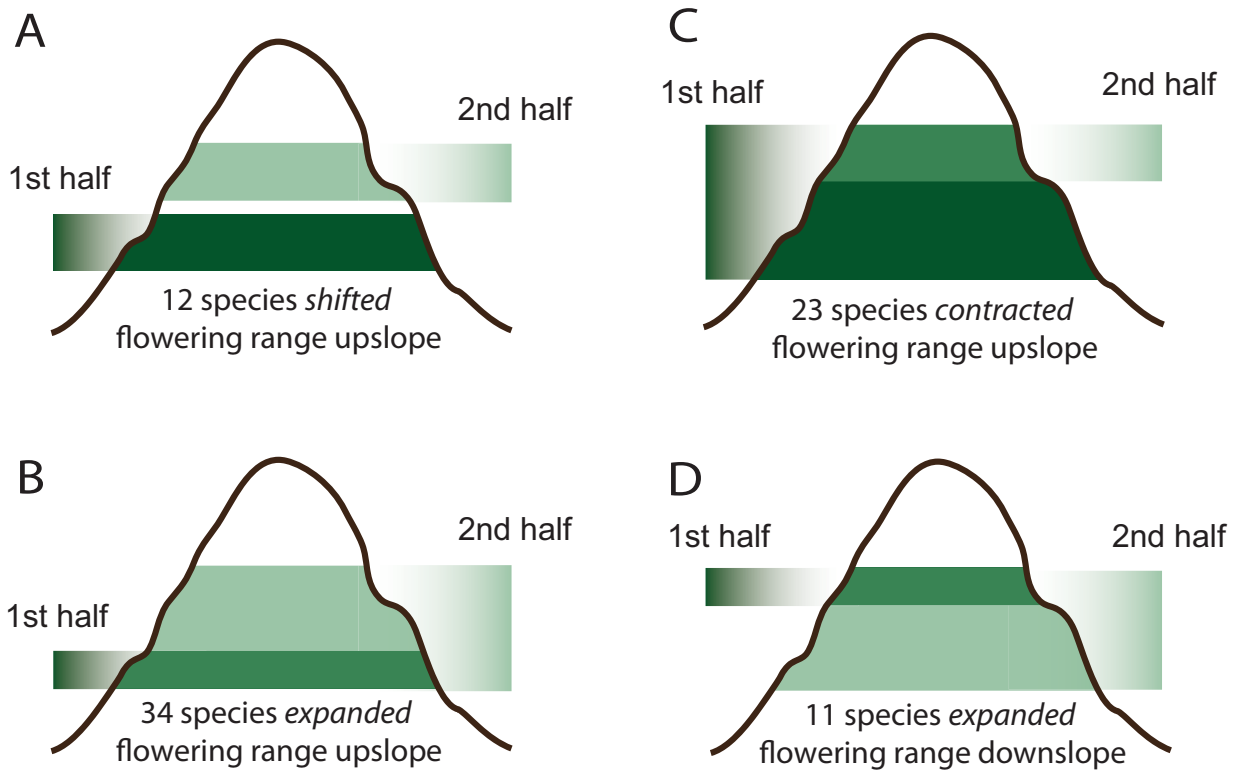

Figure 1. Bertelsen has witnessed shifts in the flowering ranges of species between the first half of the record (1984–1993) and the second half (1994–2003). The four most common changes have been: A) 12 species shifted flowering range upslope, B) 34 species expanded flowering range upslope, C) 23 species contracted flowering range upslope, and D) 11 species expanded flowering range downslope. Figure modified from Crimmins and others (2009) "Flowering range changes across and elevation gradient in response to warming summer temperatures."

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for example, species must migrate longer distances to reach higher elevations. On the other hand, on the steeper slopes of a sky island, a one-degree F drop in temperature can be reached in only a mile or two, as temperatures generally decreases by 1 degree F for every 350 vertical feet.

As a result, in mountainous biomes species can move at a slower rate than they can in flatter environments such as grasslands and deserts, making it easier for flora and fauna to keep pace with climate change. In desert environments of the Southwest, the authors suggest that species will be required to move at about 0.5 miles per year to survive. It remains to be seen which species will adapt and which will disappear.

Ecosystem changes and responses to extreme seasonal climates

Dave Bertelsen is paying close attention to the changes in the flora and fauna in the Finger Rock Canyon. In the past decade he has noticed that the numbers of Mohave and spineless prickly pears are increasing, which is expected because cacti thrive in hot climates. He also is witnessing how closely connected the ecosystem is to seasonal climate.

The summer of 2009 shaped up to be one of the driest on record in the Tucson area and in many regions around the Southwest. Many parts of Arizona experienced the driest monsoon since 1950, including southeast Arizona, where rains totaled only 68 percent of average. Although New Mexico was not as dry, most regions received below-average rainfall as well. The plants responded.

"The quantity of blooming annuals plummeted last summer. The scarlet morning glories usually number in the millions, literally, and not one plant flowered last summer. Most other common annuals also showed this pattern. I have never seen that before. It was just unbelievable," Bertelsen said.

While scant rains defined the 2009 monsoon season, the flowering crash also may have been related to the timing and spacing of rains.

"Last summer the annual plants didn't germinate, and I think the spacing between the rains was too far apart," Bertelsen said. "Unless you have pulses of rain to continue to keep the ground moist, plants don't reproduce."

Animal sightings also were down following the dry monsoon. On an average day in November, Bertelsen normally sees about 100 birds. Before the winter rains came in January, bird sightings dipped to around 30.

The dry weather finally broke in January, when a cavalcade of storms drenched many parts of the Southwest. But because November and December were dry, Bertelsen expected a poor spring flowering season. He was mistaken.

"I saw 154 species in bloom in early May, which was a record for a single day in spring. Perhaps the cool spring gave the plants an opportunity to use the winter precipitation more than in the past," he said.

The close connections between temperatures and the timing and amount of rains emphasize the need to better understand future climate scenarios, particularly the monsoon season. Although climate model projections are highly uncertain for summer precipitation, Bertelsen's observations serve as a good example of what could happen. It's possible that a warmer spring combined with a dry November and December could cause spring annuals to bust, while summer annuals would be scant if the monsoon fizzles.

Looking ahead

What concerns Bertelsen is that the Sonoran Desert ecosystem evolved over thousands of years, but current changes are occurring much more rapidly.

"If I can see changes in 24 years of data, things are happening really fast. I'm worried that the diversity will plummet if the ecosystem can't adapt quick enough," Bertelsen said.

It's also difficult to look into the past for clues about the future because most studies of species responses to climate change pertained to periods in which the Earth warmed from colder times, or vice versa. Today, warm climates are getting warmer, and the rate of temperature change projected for the future is 10–100 times faster than that experienced during the transition from cool to warmer climate during the last glacial retreat. This may require species to migrate at rates much faster than those observed during in the past and suggests that rapidly changing climate will favor more mobile and opportunistic species, resulting in altered community composition and structure, ecosystem properties and processes, and reducing biodiversity.

"If I could fast forward 20 years and hike the trail, I may see an open oak scrub savanna in place of oak-pine forest in the higher elevations. However, it's hard to know right now. But, I do think the native biodiversity will decline."