Using citizen science to study saguaros and climate change at Saguaro National Park

By Don E. Swann, Adam C. Springer, and Kara O'Brien

Abstract

The Saguaro Census is a long-term monitoring project in Saguaro National Park, Arizona, that features citizen scientist volunteers who learn about ecological change in the park while gathering data on saguaros. In 2010, more than 300 volunteers measured more than 20,000 saguaros. Results of the 2010 Saguaro Census suggest that, after years of decline in at least some areas of the park, the population of this slow-growing, long-lived southwestern cactus species has increased dramatically in recent decades, following the end of a long drought in the 1950s and a warming trend since the 1970s. Citizen science has the potential not only to help parks gather large amounts of data but also to promote greater understanding and communication of natural resources management and climate change science.

Key words: citizen science, climate change, long-term monitoring, saguaro, Saguaro National Park

IN 2009, SAGUARO NATIONAL PARK was declared one of America's 25 national parks most imperiled by climate change (Saunders et al. 2009). Climatologists have predicted hotter and drier conditions in the Southwest (Barnett et al. 2004; Seager and Vecchi 2010), increasing the urgency for the park not only to understand impacts of climate change on natural resources but also to better communicate them to the public. Volunteer citizen scientists regularly help resource managers at the park efficiently gather large amounts of field data. At a time when there is much confusion and misinformation about climate change, this type of hands-on participation also has educational value by helping demystify science. In 2010, volunteers played a major role in the Saguaro Census, a monitoring program designed to study long-term ecological change in the park.

Saguaros (*Carnegiea gigantea*) are large columnar cacti that can live more than 200 years. Beloved by Arizona residents and visitors, they are also well studied. One of the longest annual monitoring programs for any species in a national park occurs at Saguaro, where some plots have been monitored for 70 years (and currently by researchers Tom Orum and Nancy Ferguson).

Saguaro National Park was established as a national monument in 1933 to protect the magnificent stand of large saguaros, known as the "Cactus Forest," in the Rincon Mountains east of Tucson. The Tucson Mountain District, west of Tucson, was added in 1962, and after further expansion in 1994, the monument became a national park. Even in the 1930s many older giants were observed to be dying, and few young saguaros could be found. The decades-long decline of the Cactus Forest has been dramatically captured in repeat photographs compiled by saguaro researcher Ray Turner (fig. 1, next page). In 1962, researchers predicted that the species would disappear from the park by 2000.

Although many factors influence saguaro recruitment, growth, and survival, research reveals that climate can be a major driver of population change. The saguaro is a subtropical plant that tolerates frost but not freezing, and severe freeze events in the 1970s are believed to have been the proximate cause of mortality of many older and very young individuals (Steenbergh and Lowe 1983). Though adults have a high tolerance for extreme heat and drought, young saguaros are very sensitive to these factors; thus recruitment appears to be episodic, coinciding with cooler, wetter periods (Drezner and Balling 2002). In addition, as a desert plant the saguaro is not fire-adapted, which may limit its distribution at higher elevations where flammable grasses are more abundant. Because minimum winter temperatures have become warmer in the Sonoran Desert during the past few decades (Weiss and Overpeck 2005), and climate models predict future decreased winter rainfall (Seager and Vecchi 2010), climate change may thus have a complex influence on saguaros—positive in response to warmer winters, but negative because of increased drought. A particular concern is that warmer winters are believed to promote an invasive African grass, buffelgrass (*Pennisetum ciliare*), that competes with saguaros and promotes fire in a desert ecosystem dominated by plants (like saguaros) that have not evolved with fire (Stevens and Falk 2009).

The Saguaro Census

Every 10 years since 1990, scientists have gathered at the park to seek a greater understanding of the long-term dynamics of the park's signature species in relation to its environment. Known as the Saguaro Census, the monitoring activities focus on individual saguaros, saguaro demographics, and associated Sonoran Desert plants

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1935 PHOTOGRAPHER UNKNOWN

1998 RAY TURNER

Figure 1. Repeat photos from 1935 (top) and 1998 (bottom) reveal dramatic changes in the saguaro population of the Cactus Forest area in the Rincon Mountain District of Saguaro National Park.

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Figure 2. Volunteer Matt Christensen measures a saguaro during the Saguaro Census.

on 45 randomly located, 4-hectare (9.9-acre) plots. The random distribution of study plots across a wide elevation gradient (680–1,231 m [2,231–4,039 ft]) provides an opportunity to detect changes in cactus distribution that may be related to climate or other landscape-level processes. Results of the Saguaro Census, such as estimates of the total saguaro population, have become an important part of the park's interpretive program. In 2000, when the census was first repeated, it also received significant publicity and volunteer support, and park staff saw its potential to build greater awareness of long-term ecological processes.

In 2010 the park made citizen science the core of the census. We hired an intern to coordinate volunteers, create educational products, and develop a process for leading volunteers, including methods for ensuring and evaluating data quality. From September 2009 through October 2010, more than 300 volunteers from local schools, hiking clubs, and businesses, directed by a core group of volunteers and park staff, counted and measured more than 20,000 saguaros (fig. 2). Previsit materials and an on-site orientation provided volunteers with background on ecological change at the park and why we conduct the census. Following a safety review in the field, volunteers were broken into small groups, each led by an experienced volunteer or biological technician. The group received training on how to use a clinometer to estimate cactus height, read metric rulers, identify bird cavities, and record data. Then they searched for, measured, and flagged all saguaros encountered along belt transects within the plot. After the first pass, the groups switched places and re-searched for any saguaros that could have been missed. Following their day in the field, the volunteers could visit the park's Web site to view photos and data graphs, and to compare their results with those of 1990 and 2000.

Results

Have changing climatic conditions already affected saguaro populations? Data from the Saguaro Census suggest so, but with a complexity that is characteristic of the natural world. The saguaro population in the park has surged since 1990, more than doubling on many plots—positive news for both volunteers and visitors (fig. 3, next page). We estimate the total saguaro population to be 1,896,030 (±228,163) in Saguaro National Park, an overall increase of nearly 66% since 1990. Although saguaro age cannot be directly measured, estimation of

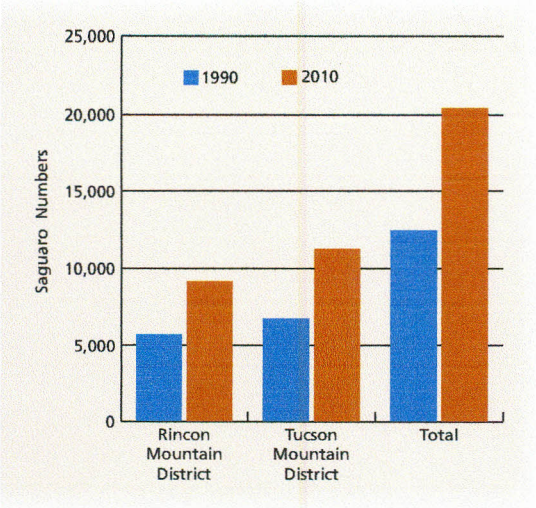

Figure 3. Number of saguaros greater than 10 cm (3.9 in.) in height detected on 45 Saguaro Census plots sampled during 1990 and 2010 in Saguaro National Park.

age based on mean local growth rates suggests recruitment began increasing in the 1960s following the severe drought of the 1950s, and accelerated in the 1980s after the end of the cold period a decade earlier. Alternative explanations for the increase are the elimination of cattle grazing and the regrowth of "nurse trees," such as the foothills palo verde (*Parkinsonia microphyllum*), that protect young saguaros from environmental extremes. The park and the NPS Sonoran Desert Network have been studying the effects of removing cattle from park lands. Based on a repeat survey conducted in 2007 of perennial plant species on treatment and control plots established in 1976, scientists with the network conclude that the effects of time outweigh the effects of grazing (Andy Hubbard, unpublished data). This suggests that climate may be more important than previously believed in controlling saguaro numbers. Conversely, the results of the 2010 Saguaro Census also suggest that, since the mid-1990s, recruitment of young saguaros has slowed. Because of the difficulty of detecting very small saguaros (a 10-year-old is approximately 4 cm [1.6 in.] in height), it is too soon to know the extent of this decline, which coincides with Tucson's hottest and driest decade on record (NOAA 2010). In addition, the park experienced an unusually cold period this past winter, in February 2011, which may have increased saguaro mortality.

Like many protected areas, Saguaro National Park faces extraordinary challenges in natural resource stewardship, especially during a time of climatic change. The saguaro's iconic role in southern Arizona makes it an ideal species to engage the public as true partners who can help us better understand these changes, respond to threats, and, most importantly, continue to learn as we move forward in the face of uncertainty. Hidden beneath the current landscape view of the park (see fig. 1) are not only many young saguaros growing slowly beneath nurse trees, but a complex story of ecological change occurring over years and decades. Citizen scientists who foray into the field to help us monitor saguaros have the opportunity to experience the process of doing science while learning about the complexity of managing natural resources in a rapidly changing world. In developing a deeper appreciation for the connection between science and the community, they may become some of our best advocates to communicate climate change issues.

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