



Demographic changes over >70 yr in a population of saguaro cacti (*Carnegiea gigantea*) in the northern Sonoran Desert



Joshua L. Conner^{a,*}, Theresa Foley^b, Daniel E. Winkler^c, Don E. Swann^a

^a Saguaro National Park, 3693 S. Old Spanish Trail, Tucson, AZ 85730, USA

^b Sonora Environmental Research Institute, Inc. (SERI), P.O. Box 65782, Tucson, AZ 85728, USA

^c Department of Ecology and Evolutionary Biology, University of California, Irvine, 321 Steinhaus Hall, Irvine, CA 92697, USA

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ABSTRACT

We studied changes in a population of saguaro (*Carnegiea gigantea*) cacti on a 259 ha plot in the northern Sonoran Desert (Saguaro National Park) that was first surveyed in 1941. With the help of citizen scientists, we mapped and measured the height of all detected individual saguaros. The total number of detected saguaros was 13,304 in 1941 and 9023 in 2012, a 31.4% decrease. The population in 1941 consisted of mostly larger, older individuals, whereas in 2012 it was dominated by smaller, younger individuals. Based on estimated years of saguaro establishment, a period of high establishment in the mid-late 1800s was followed by many decades of poor establishment. However, establishment surged from the 1970s to early 1990s but has been very low since. Comparisons with other long-term saguaro studies suggest that the dramatic demographic changes in this area have resulted from climatic factors, most notably recent long-term drought and higher temperatures, in combination with land-use changes, especially loss of nurse trees due to wood-cutting early in the twentieth century.

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1. Introduction

The saguaro cactus (*Carnegiea gigantea* [Englm.] Britt. and Rose) is a keystone species in Sonoran Desert ecology, with >100 species of fauna utilizing the plant for survival (Drezner, 2014). Precipitation is the primary limiting factor regulating the occurrence of saguaros on the western edge of the range (Steenbergh and Lowe, 1977) and saguaro populations at the eastern and northern extent of the range are limited by the occurrence of >24 consecutive hrs of subfreezing winter temperatures (Hastings, 1963; Steenbergh and Lowe, 1976). Saguaro initiate growth after the start of the summer monsoon and growth rate across the range is strongly correlated with summer precipitation (Drezner, 2005).

The Sonoran Desert has both winter and summer rainy seasons caused by different atmospheric phenomena. Winter precipitation occurs when frontal systems originating from the Pacific Ocean follow a southern path across Arizona. Summer precipitation is

caused by the North American Monsoon, which occurs when intense solar heating causes a shift in the pattern of high and low pressure systems in the Southwest and draws moisture northward from the Gulf of California, the Gulf of Mexico, and the eastern tropical Pacific Ocean (Sheppard et al., 2002). A period of hot, dry weather, often referred to as the foreshummer, occurs between these two rainy seasons, but a precipitation shortfall in either season can lead to drought (Weiss et al., 2009). Rising average summer temperatures result in more arid conditions and increase the rate of evapotranspiration (Weiss et al., 2009). The Cactaceae family is one of the most threatened taxonomic groups worldwide (Goettsch et al., 2015) and, as one of the most studied members of its family, the saguaro provides one of only a few examples of biotic and abiotic impacts on cacti demographics (Drezner and Lazarus, 2008). Thus, a fine-tuned understanding of saguaro demographics and climatic influences on this species can greatly enhance predictions of Cactaceae dynamics under climate change scenarios (Téllez-Valdés and Dávila-Aranda, 2003).

Saguaro National Park (SNP), located near the eastern limit of the saguaro population (Fig. 1), was originally established as a national monument in 1933 to protect an area known as the “Cactus Forest,” which was considered to contain the finest stand of the giant saguaro cactus in the U.S. (Steenbergh and Lowe, 1983). In

* Corresponding author.

E-mail addresses: converjl@mail.uc.edu (J.L. Conner), theresa.foley3@gmail.com (T. Foley), winkler.de@gmail.com (D.E. Winkler), don_swann@nps.gov (D.E. Swann).

¹ Present Address: Department of Geography and GIS, University of Cincinnati, 401 Braunstein Hall, Cincinnati, OH 45221.

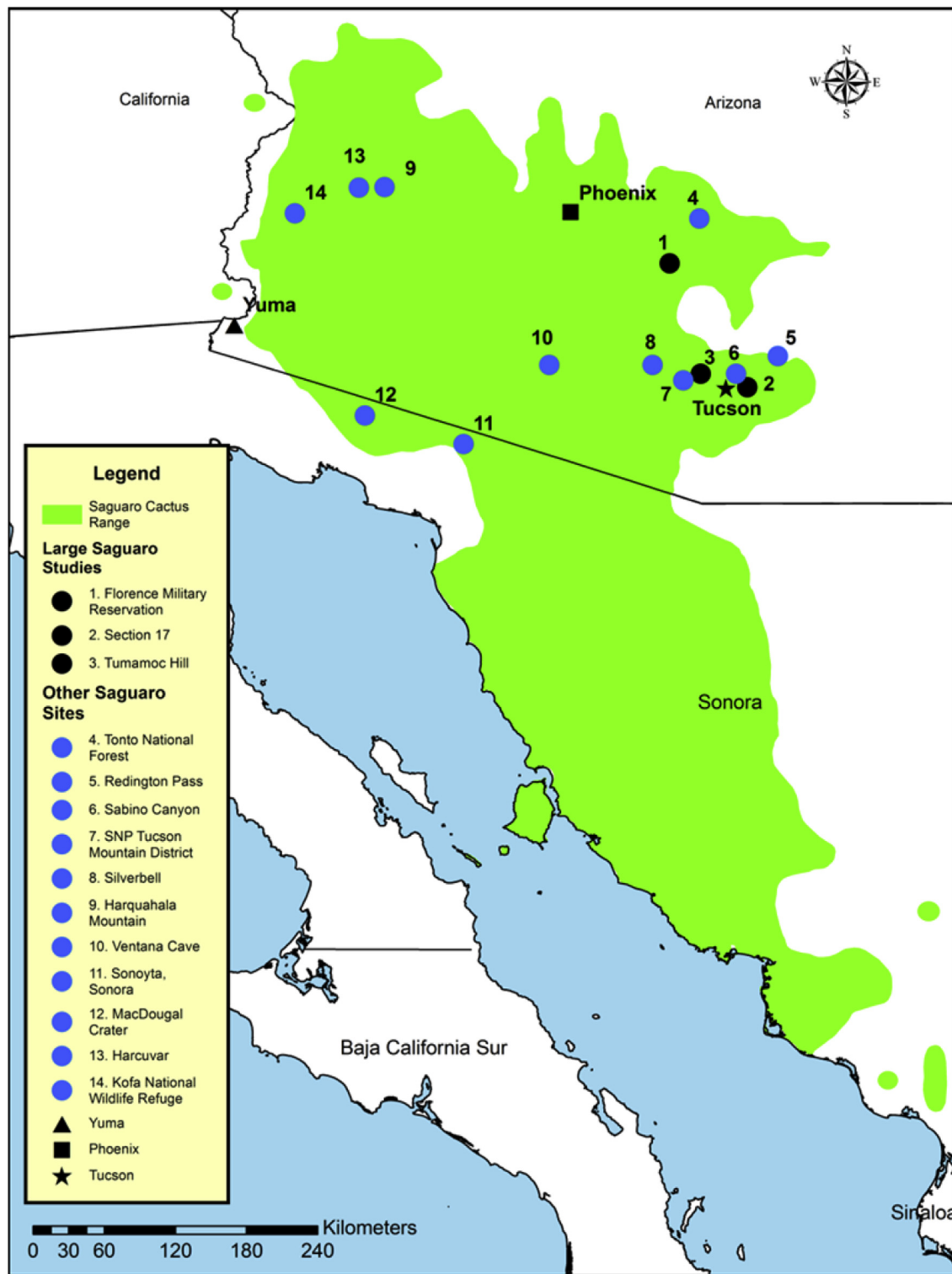


Fig. 1. The location of saguaro studies in the northern Sonoran Desert. 1. Florence Military Range (Danzer and Drezner, 2010); 2. Section 17 (this study); 3. Tumamoc Hill (Pierson and Turner, 1998); 4. Tonto National Forest (Campbell et al., 2011); 5 through 12 (Pierson et al., 2013); 13. Harcuvar (Drezner, 2006b); 14. Kofa National Wildlife Refuge (Drezner and Balling, 2008). The range of the saguaro cactus was obtained from the United States Geological Survey (Little, 1976).

1939, National Park Service (NPS) staff were alarmed by a highly visible die-off of saguaros in the Cactus Forest. Some researchers hypothesized that the widespread mortality was the result of a contagious bacterial disease (Gill, 1942). To determine if removing diseased saguaros would improve survival of healthy individuals,

researchers divided a 259 ha area (1 mi²) of the Cactus Forest (Section 17 of Range 16E and Township 14S; referred to as “Section 17” in this study), into 64, 4.05 ha plots (Appendix 1, electronic version only). All saguaros showing signs of bacterial infection were removed mechanically from the 32 southern plots of Section 17,

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