

Saguaro Initiatives at Desert Botanical Garden: generating tools and resources to save threatened cactus species

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Abstract

The increasing frequency and intensity of extreme heat events in the Phoenix Metropolitan Area have raised concerns about the survival of saguaros (*Carnegiea gigantea*) in urban environments. While saguaros are iconic symbols of the Sonoran Desert and known for their resilience to arid conditions, increasing temperatures, prolonged drought, and urban heat island effects may be accelerating their mortality. Community reports of dying saguaros prompted an urgent need for research and conservation action. This issue extends beyond the Phoenix Valley. Climate projections suggest that up to 60% of cactus species could experience habitat loss, with as many as 90% being negatively affected when combined with other human-driven stressors. Despite these alarming observations and predictions, scientific data on saguaro mortality and resilience remain limited, making it critical to study how these long-lived plants are responding to changing environmental conditions.

In response, we launched the *Saguaro Initiatives* at the Desert Botanical Garden (DBG)—a suite of community science and conservation programs designed

to document, protect, and sustain urban saguaros while raising awareness of broader cactus conservation challenges. These initiatives include the *Saguaro Census*, which tracks saguaro health and demographics through citizen science; the *Saguaro Dead Report*, a tool for recording mortality trends; and the *Saguaro Genomics and Conservation Initiative*, which analyzes genetic diversity and climate adaptation. Additionally, we have established a *Saguaro Seed Bank* to safeguard the species' genetic diversity and created a *Saguaro Nursery* where volunteers propagate seedlings for future restoration efforts.

These projects highlight the urgency of saguaro conservation, demonstrating that protecting native biodiversity cannot rely solely on institutions—it requires a collective effort. Through research, education, and public engagement, DBG *Saguaro Initiatives* empower the community to take action. By leveraging the cultural and ecological significance of saguaros, we aim to shift conservation beyond scientific circles and into neighborhoods, homes, and urban spaces. The survival of saguaros—and cacti worldwide—will depend on our willingness to act.

Are cacti dying in the desert?

The Phoenix Metropolitan Area is experiencing increasing and unprecedented climate extremes, with prolonged heat waves and record-breaking summer temperatures exceeding 110°F (45°C) for several consecutive days. These extreme conditions pose significant challenges for all living organisms, but they are especially harsh on those that cannot move to seek shade—plants. When I (author Tania Hernández) joined the Desert Botanical Garden as a researcher in 2021, I quickly became aware of an extraordinary phenomenon unfolding in the Phoenix Valley. It was not just about the rising temperatures, nor solely about the impact of extreme heat on cacti. What struck me most was something deeper: the profound social and cultural significance of the saguaro. Unlike any other cactus—or plant—I had encountered anywhere in the world; the saguaro holds an unparalleled place in the hearts of this community. Their presence and their resilience resonate far beyond ecology, shaping the very identity of the region (Figure 1). The potential loss of this icon in the Phoenix Valley is both biologically and culturally devastating.

I realized this phenomenon immediately after my first summer. Having spent time in both Hermosillo, Sonora, and Tucson, Arizona, I was already familiar with extreme heat. However, by the end of that summer, something unusual was happening—the community began reaching out to the DBG with urgent concerns about saguaros struggling to survive in urban

conditions. My colleagues and I were overwhelmed by the sheer volume of phone calls, emails, and media inquiries. People wanted to understand why saguaros—icons of the Sonoran Desert, known for their resilience to heat and drought—were suddenly dying in cities. More than that, they were desperate for guidance on how to help them survive. This was unlike anything I had ever witnessed elsewhere in the world with any other plant. The saguaro is more than just a species—it is a defining symbol of place, a source of cultural identity, and a unifying element of the landscape. The deep concern over their possible disappearance from urban environments underscored even more their extraordinary significance to the people of this region.

Although at that moment science did not yet have a definitive answer to the community's concerns, we knew this was coming—this was nothing new. The plight of the saguaro reflects a much larger crisis affecting the entire cactus family, which includes around 1800 species across the Americas. According to the International Union for Conservation of Nature (IUCN) Red List, one-third of all cacti are threatened with extinction due to habitat loss, poaching, and other human-driven pressures, making them one of the most threatened plant groups worldwide (Goetsch et al, 2015); and climate change compounds these threats (Pillet et al, 2022). For years, our collaborator and coauthor Michiel Pillet has been analyzing the climatic conditions inhabited by different cactus



Fig. 1 A few examples of the vast saguaro iconography that can be found on the streets of our cities in the Phoenix Metropolitan Valley Area including drawings and shapes. These can be seen everywhere in the city, yet the actual presence of saguaros in our green spaces is becoming less common. (Photo credits: T. Hernández & T. Estrada)



Fig. 2 Urban saguaros are struggling in city areas, where urban heat island (UHI) effects pose important challenges to their survival. Although receiving regular irrigation and even fertilization, it is not uncommon that saguaros collapse, in particular during or after the hottest and driest months of the year. (Photo credit: J. Davis)

species. He uses advanced statistical models to predict how these conditions will change under future predicted climate scenarios, and how this will affect the distribution of cacti. His research clearly shows that most cactus species are projected to lose part of their suitable climatic habitat (Pillet et al, 2022). Up to 60% of cactus species may experience losses, and as many as 90% could be negatively affected when combined with other environmental stressors (like drought). Reading these statistics in scientific papers is alarming, but witnessing this firsthand takes that alarm to an entirely different level. The decline of suitable habitat due to climate change is no longer a distant prediction—it is happening now in the Phoenix Valley, where extreme summer heat waves and non-cooling nights are having a deadly impact on saguaros (Figure 2; Wilder et al, 2025). For those of us who have spent our lives in the desert, this crisis may not seem as shocking. We normalize what we shouldn't. However, when I presented my work at the International Botanical Congress in Madrid, Spain, the reaction was stark. People were astonished to learn that, yes, even cacti—plants synonymous with resilience—are dying in the very deserts they have long dominated.

The Saguaro Initiatives

After recognizing the urgent need for action to protect and preserve cactus diversity, and although it is not yet classified as threatened, my team at the DBG decided to use the saguaro cactus as a flagship species for conservation. If we can better describe and explain what is happening to saguaros—a plant that people deeply connect with—we might also be able to highlight the vulnerability of other cactus species. Saguars have the potential to shift public perception, demonstrating that conservation is not solely the responsibility of scientists and institutions but a collective effort in which everyone plays a role. With this in mind, we launched the **Saguaro Initiatives** (dbg.org/research-conservation/saguaro-initiatives/), a suite of community science and conservation programs designed to document, protect, and sustain saguaros in an era of climate change. These initiatives aim not only to safeguard saguaros but also to use them as a powerful symbol to raise awareness about the broader threats faced by cacti and succulents worldwide.



Fig. 3 One of the flyers produced by Jeny Davis and DBGs Marketing Department to advertise the Saguaro Census. Each year we set a new goal to improve the program, and in 2025 the goal was to invite students (middle school, high school and college level) to participate. We are giving prizes to the participants with the highest number of observations, in hopes that it becomes a healthy competition.



Fig. 4 Saguaro Census Prize package for the participants with the highest number of observations. It includes a t-shirt, hat, stickers and patch, free entrance to the Garden, a membership and for top observers, a dinner for two in the Garden's restaurant and an REI gift card. Of course, it also includes a certificate. One of our more enthusiastic volunteers, Walt Nielsen, has surveyed over 2,600 saguaros during the past 3 years. (Photo credit: T. Hernández)

Saguaro Census

Before we could effectively address the challenges facing urban saguaros, we first needed to answer some fundamental questions: How many saguaros exist in the Phoenix Valley? Where are they concentrated? How healthy are they? Surprisingly, this basic information was lacking. To fill this gap, we launched the **Saguaro Census**, a large-scale community science effort to track the health and demographics of urban saguaros (Figure 3). The first Saguaro Census campaign began in 2022, and we have been repeating it yearly with a public engagement campaign every May, though volunteers can contribute observations year-round. Using the iNaturalist app, participants document saguaros across the Valley, recording key details such as size, habitat, and general health.

Because saguaros are easily recognizable—even to those without any background in plants—this initiative is accessible to anyone willing to participate. Volunteers are also asked to record details such as the number of arms and holes in each saguaro, as these features provide valuable ecological insights. This activity serves multiple purposes: it increases community awareness of saguaros in their surroundings, encourages people to actively monitor their health,

and reinforces their value as an essential part of the urban green landscape. It also highlights the importance of these plants, and their cultural and ecological contributions. At the same time, the data collected through these observations is critical for understanding the state of urban saguaro populations and identifying potential threats to their survival. Beyond gathering scientific data, the Saguaro Census has become a powerful tool for public engagement, extending DBG's conservation efforts beyond its physical grounds and into the broader community. It has also fostered a growing network of saguaro advocates throughout the Valley, with more people joining each year, strengthening the collective effort to protect this iconic species (Figure 4).

Over the past few years, the Saguaro Census has provided valuable insights into the state of urban saguaros in the Metropolitan Phoenix area. One of the most striking findings is that most saguaros are medium to large in size, indicating a scarcity of young saguaros to replace the aging population. This raises concerns about long-term regeneration and highlights the need to better understand the factors limiting the practice of establishing young saguaros. Another key observation is that the majority of urban saguaros are

Figs. 5a-c According to Saguaro Census results, most of the urban saguaros in the Phoenix Metropolitan area are in residential areas, particularly people's yards. Homeowners are the most important stewards of our urban desert icon.



found in residential areas rather than in parks or public spaces, emphasizing the significant role homeowners play in their stewardship and conservation (Figure 5). Despite widespread concerns about their decline, most recorded saguaros appear to be in relatively good health, offering a more hopeful outlook than initially expected. Additionally, observations of holes in saguaros have provided important ecological insights, revealing their role as habitat for birds and other urban wildlife, reinforcing the ecological importance of saguaros even in highly urbanized environments. As data collection continues, a comprehensive public report summarizing our findings will be released following the fourth edition of the Census in 2025.

Despite the progress made through the Saguaro Census, this effort remains an enormous undertaking, and continued community participation is essential. As we prepare for the 2025 edition, our focus is on expanding engagement and improving the quality of data collected. We are also in need to expand the Census into underrepresented cities and areas within the Valley. We are observing some large gaps in saguaro presence that need to be confirmed as naturally occurring or a result of sampling bias (Figure 6).

Fig. 5a A majestic saguaro during an evening drizzle in a neighbor's front yard in Tempe, Arizona.



Fig. 5b shows a line of saguaros at the Pueblo Museum in Phoenix AZ.



Fig. 5c shows the same pattern at the Scottsdale's Museum of the West. These landscaping projects require the constant replacement of decaying saguaros with new ones. Transplanting saguaro is expensive and oftentimes a failing process (Photo credits: T. Hernández).

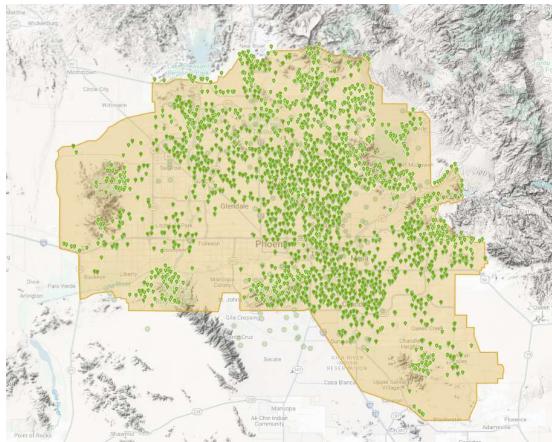


Fig. 6 iNaturalist map, showing the Metro Phoenix Area boundary used for the project, and all observations made for the Saguaro Census. As can be seen in the map, some extensive areas in the Valley have no observations. We need more information and systematic surveys to determine if those gaps are real (depleted of saguaros) or deficient sampling efforts.

Another top priority is to engage younger generations by involving high school students and ASU (Arizona State University) undergraduates in this initiative. Every single observation contributes to a deeper understanding of urban saguaros and their future in a changing environment. Whether documenting just one saguaro or many, each submission plays a role in protecting this iconic species. The Saguaro Census is an opportunity for the community to take part in conservation, ensuring that saguaros remain a defining feature of the desert landscape for generations to come.

Saguaro Dead Report and Mortality Rates in the Phoenix Valley

There was one crucial detail we hadn't considered when launching the Saguaro Census: iNaturalist is designed for documenting living organisms, not tracking the dead ones. While the Census has provided valuable insights into the current status of saguaros across the Valley, it does not capture data on mortality. This left us with critical unanswered questions: Are saguaros dying at higher rates now than in the past? Is saguaro mortality concentrated in specific areas of the Valley? Are deaths more frequent at certain times of the year, such as the end of summer? What are the primary causes of saguaro mortality?

To fill this gap, we created the **Saguaro Dead Report (SDR)**—a simple but effective tool that allows the public to report dead saguaros through a Google Form. Participants can provide details such as location (or approximated location if they prefer), estimated size, possible cause of death, and even submit photos. Remarkably, even if a saguaro died years ago, its loss often remains a vivid memory for those who lived alongside it. The collapse of such massive, long-lived plants is a striking event, particularly for homeowners who have cared for them for decades [1]. Many people recall exactly when their saguaro fell and even keep photos as a way to remember it. The SDR offers a way for them to share these experiences while helping us build a broader understanding of saguaro mortality patterns across the urban landscape.

Unfortunately, without a large budget for publicity and outreach, survey efforts alone are not enough to provide a comprehensive picture of saguaro mortality. To overcome this limitation, our team of students and volunteers has adopted an accumulation of evidence approach, gathering information from multiple sources to build a clearer understanding of how and why saguaros are dying. In addition to the Saguaro Census and the Saguaro Dead Report, we have been analyzing data from the Desert Botanical Garden's Saguaro Inventory, which provides high-quality records of saguaro health and mortality spanning the last 15 years within the Garden's grounds. We are also reaching out to local landscapers and nurseries to obtain data on saguaro removals and consultations, as these professionals often witness the first signs of saguaro decline across the Valley. Since environmental conditions in arid regions like the Sonoran Desert fluctuate significantly from year to year, it remains unclear whether recent concerns about saguaro mortality reflect a genuine increase in deaths or a recurring seasonal pattern of heightened concern during the extreme summer months. To investigate this, we are conducting a media analysis to track how saguaro health and heat-related mortality have been covered over time. By systematically reviewing news articles, reports, and videos from the past decade, we are assessing how frequently concerns about saguaros appear in the media and accounting for the general increase in media output over time. Collaborating with marketing experts at the Desert Botanical Garden will help refine this analysis, ensuring that we capture meaningful trends rather than fluctuations in media attention.

To further supplement these data, we are conducting structured interviews and surveys with senior homeowners, who often have firsthand knowledge of saguaros in their neighborhoods. Their long-term observations provide valuable anecdotal evidence of whether saguaro deaths are truly more frequent now or whether these concerns have always been part of the summer cycle. Additionally, we are establishing baseline comparisons with wild populations to contrast urban saguaro mortality with those in more natural settings. This includes analyzing data from the Tumamoc Hill Saguaro Census, a long-term ecological research site, and conducting an extensive literature review on saguaro demography, drawing from the work of experts such as Don Swann and Alberto Bürquez. By combining multiple sources of information, we aim to build the most complete picture yet of saguaro mortality in the urban landscape and determine whether climate change is accelerating their decline.

Understanding mortality rates in long-lived organisms like saguaros is a complex challenge that requires a multifaceted approach. By creatively combining

different sources of evidence, we aim to determine whether saguaro mortality is truly increasing in the Phoenix area due to extreme heat and drought or if these observations are part of natural demographic cycles. Through qualitative methods such as media analysis and quantitative approaches like surveys and long-term censuses, this study will provide a clearer picture of how saguaros are responding to changing environmental conditions. Beyond identifying mortality trends, we hope to establish a standardized framework for monitoring saguaro health in urban areas. By integrating citizen science initiatives, structured interviews, and institutional data from the Desert Botanical Garden, we can create a model for long-term tracking that will help detect early warning signs of stress and decline. This information is crucial for informing conservation strategies and ensuring that saguaros continue to thrive in our cities despite the increasing challenges posed by extreme heat.

As this work continues, we welcome collaboration and new perspectives. If you have insights, observations, or data that could contribute to our understanding of urban saguaro mortality, we encourage you to reach out and be part of this ongoing effort to protect the most iconic plant of the Sonoran Desert.

Saguaro Genomics and Conservation

The saguaros that define the Sonoran Desert's landscape are not all the same. Genetic differences influence their ability to survive across the various environments comprised in this area, withstand extreme heat and drought, and resist disease. Documenting and understanding this genetic diversity is a crucial first step in any conservation effort. While saguaros themselves are not currently threatened, nearly 1,000 other cactus species are at risk. In response to this urgent need, we chose to use saguaro as a model species within the Cactaceae family to develop the tools, protocols, and workflows necessary for genomic research at DBG, ensuring that these methods can later be applied to other endangered cacti. Through the *Saguaro Genomics and Conservation Initiative*, we are investigating the genetic structure of both urban and wild saguaro populations to better understand how these plants respond to environmental stressors, aiming at identifying genetic traits linked to resilience, providing valuable insights into conservation strategies. This research will also help answer key questions about whether urban saguaros are a good representation of the genetic diversity of their counterparts in the wild, how they respond to prolonged heat and drought stress, and which populations may be most vulnerable to future climate shifts.

For decades, scientists have relied on traditional DNA molecular markers to study the evolutionary history and population structure of species. However,

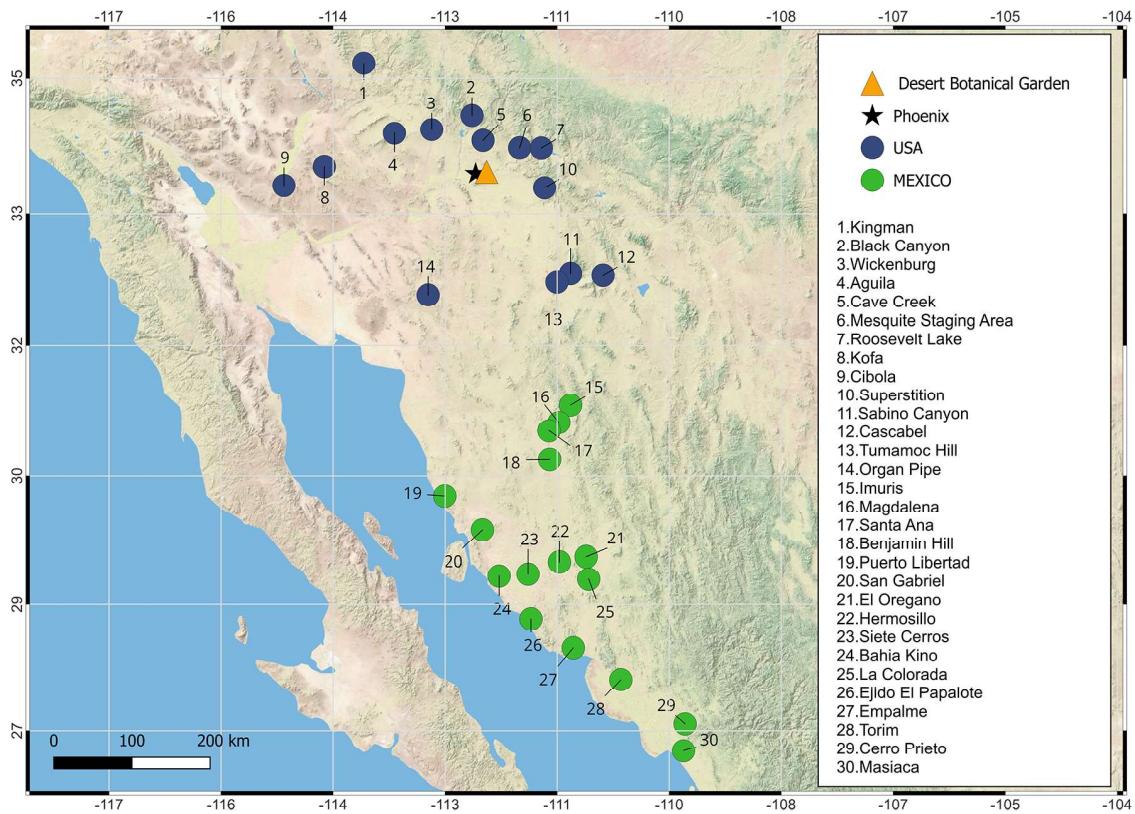


Fig. 7 Localities visited to sample saguaros for our Saguaro Genomics and Conservation project. The same localities were visited to collect fruits for the Saguaro Seed Bank.

these markers have reached their limitations, providing only a fraction of the information needed to fully understand genetic variation and adaptation. Advances in whole-genome sequencing now make it possible to analyze the complete genetic makeup of a species at an unprecedented level. New methods are being developed to apply whole-genome data to population-level studies, but these techniques must be refined and adapted for each taxonomic group. Implementing them in wild plants like cacti is particularly challenging, requiring time, specialized expertise, and significant resources. However, developing genomic resources for the Cactaceae family is crucial for advancing both conservation and evolutionary research.

One of the most important biological challenges when working genetics in cacti are DNA extractions. Their high water content, mucilage, and secondary metabolites complicate the chemistry behind extraction and sequencing. To address these difficulties, we are using saguaro to refine and standardize sampling techniques, develop optimized DNA extraction protocols, and establish bioinformatics pipelines specifically designed for cacti. By improving genome assembly, population genetics analyses, and adaptation studies, this initiative will create a foundation for future genomic research across the cactus family.

Over the past few years, we have collected tissue samples from hundreds of saguaros across the Sonoran Desert to generate high-quality genomic data (Figure 7). The logistics of this fieldwork presented significant hurdles, as next-generation sequencing requires that samples be frozen immediately upon collection. Transporting and maintaining liquid nitrogen in remote desert locations added another layer of complexity. Beyond the technical challenges, the international transport of Cactaceae biological material is strictly regulated. Although DBG holds the necessary permits, ensuring proper handling and storage during border crossings was an additional concern. To address this, we collaborated with Mexican colleagues to extract DNA on-site, allowing us to legally and efficiently ship processed samples to the U.S. for further analysis (Figure 8–11). These efforts are not only helping to develop genomic tools for saguaros but are also paving the way for improved conservation strategies for cacti internationally and across their range.

Our analyses have revealed striking patterns of genetic diversity and climate resilience in saguaros, offering crucial insights for conservation. We identified two distinct genetic lineages, each with unique adaptations to drought stress. However, despite these evolutionary advantages, neither lineage is expected to adapt quickly enough to keep pace with accelerating

Figs. 8–11 These photos illustrate how we take samples of stem tissue on the field. Although a small piece of stem would be enough, oftentimes DNA extractions for cactus require to process much more, particularly for new whole-genome sequencing techniques. We cut pieces of stem, wrap in aluminum foil and drop in liquid nitrogen for immediate freezing, which maintains the integrity of the DNA molecule. Not only traveling with a liquid nitrogen tank is a challenge, but finding a local provider might be difficult, particularly in remote areas.



Fig. 8



Fig. 9

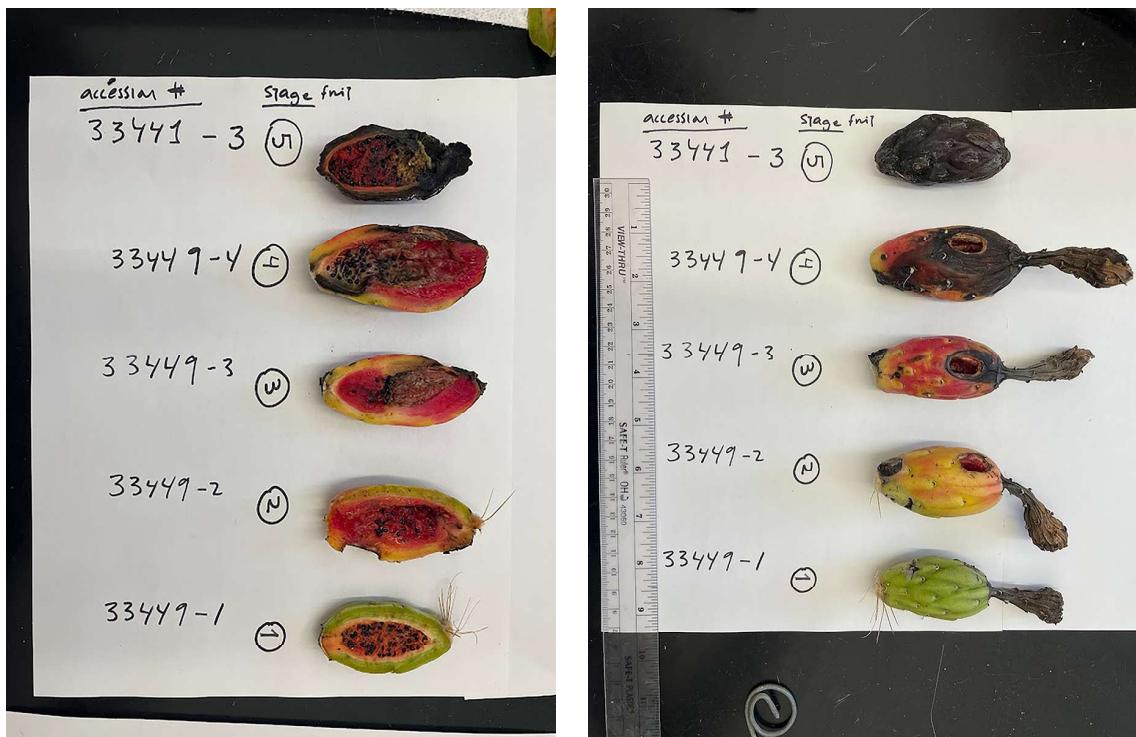


Fig. 10



Fig. 11

Figs. 12a–f Saguaro Seed Bank fruit collection. It is tricky to determine the right time to collect saguaro fruits, since it changes with latitude and condition of the plants; and we were only able to visit each locality once.



Figs. 12a, b The best fruits have a hint of red but the birds might get to them first.



Fig. 12c In our experience, collecting green fruits is not very useful, since they won't ripe separated from the plant.

climate change. Alarmingly, projections indicate that the Mexican genetic lineage is at risk of disappearing entirely in the coming years if drought conditions persist. These findings underscore the urgent need for conservation strategies that consider the genetic diversity of saguaros and their ability to withstand environmental pressures. We are preparing a scientific manuscript to share these results, which will help guide future efforts to protect this species. Beyond advancing research, this initiative has strengthened binational collaborations, making fieldwork, DNA extraction, and sequencing across borders more efficient. Yet, this is just the beginning. The threats facing saguaros and other cacti continue to grow, and their survival depends on proactive conservation. We invite new collaborations, ideas, and contributions to expand our understanding and ensure that these desert icons endure for generations to come.

The Saguaro Seed Bank

Seed banking is one of the most effective conservation strategies for preserving plant genetic diversity, providing a long-term safeguard against habitat loss, climate change, and other environmental threats. According to the **Center for Plant Conservation (CPC)**, seed banks serve as a critical resource for conservation, restoration, and research by storing viable



Figs. 12d, e We used an apple picker basket that we attached to a light window cleaning telescopic extension pole, that we were able to bring with us to México (Figure 12d-e). Fruits are ready during the hottest time of summer, where temperatures might as well rise above 110°F.



Fig. 12f The harvest of the day needs to be processed right away.

seeds under controlled conditions. The CPC's best practices for seed banking emphasize collecting from diverse populations, drying seeds to low moisture content, storing them at subzero temperatures, and periodically testing viability to ensure long-term preservation (<https://saveplants.org>). These guidelines help maintain the genetic diversity of species, ensuring that stored seeds can be used to support future reintroductions, ecological research, and restoration projects.

Applying these principles, we launched the **Saguaro Seed Bank (SSB)** to safeguard the genetic diversity of *Carnegiea gigantea* and establish a foundation for future conservation and restoration efforts. Over the summer of 2024, Dr. Tania Hernández and her team conducted the first large-scale seed collection campaign across Arizona and Sonora, México (Figure 7), creating the first comprehensive Saguaro Seed Bank deposited at the DBG Seed Bank. While saguaros are an iconic and ecologically vital species, their seeds had never been systematically collected and stored to preserve their full genetic diversity across their range. This initiative aimed to fill that critical gap, but the logistics of collecting and processing saguaro seeds posed a series of challenges—both biological and logistical (Figure 12). The timing of fruit collection was crucial, as saguaro fruits must be harvested at just the right stage of ripeness—when they develop a slight red tint and the pulp inside turns deep red and fleshy. As we quickly learned, saguaro fruits do not ripe after being picked—unlike avocados, they remain stubbornly unripe if harvested too early. Adding to the challenge, saguaros flower and fruit at different times across their range, with populations in the southernmost parts of México producing fruit weeks earlier than those in Arizona. To navigate these timing differences, we relied on local informants on both sides of the border to provide real-time updates on fruit ripening. One of our most unexpected but valuable collaborators was a dedicated iNaturalist user from Navojoa, México, whom we contacted through the app, proving how digital platforms can support conservation efforts.

Once fruits were collected, processing them presented a race against time. Saguaro fruit ferments and rots quickly, sometimes within days, making the seed extraction process highly time-sensitive. The pulp had to be removed, and the seeds meticulously cleaned and dried within 48 hours to prevent mold. Since fresh fruits could not be transported across the U.S.-México border, we had to process them on-site. To accomplish this, we traveled to Hermosillo, Sonora, with a team of volunteers, renting a house where we spent several intense days cleaning and preparing seeds for storage (Figure 13). Despite working in the peak of the summer heat, the experience was both rewarding and memorable—a hands-on effort that strengthened our collaboration and deepened our appreciation for



Fig. 13. Volunteers traveled with the team to stay at a rental house in Hermosillo, Sonora, México to help process the fruits to clear and dry seeds for the Saguaro Seed Bank.

the complexities of conserving such an iconic desert species. To ensure broad representation, seed collections were made from 233 individual saguaros across 27 localities, spanning a range of environmental conditions. This effort required careful binational coordination, with volunteers in both sides of the border assisting in seed processing, cleaning, and documentation. The SSB will serve multiple purposes—not only as a genetic reservoir for research and restoration but also as an educational tool to raise awareness about the importance of conserving desert ecosystems.

At present, the Saguaro Seed Bank is in its early stages, consisting of carefully labeled plastic and paper bags of seeds (Figure 14), accompanied by a growing archive of photographs and field notes stored in a Google Drive folder. Though still in its infancy, this initiative marks a critical step toward the long-term conservation of saguaros, ensuring that their genetic diversity is safeguarded for future generations. As the project evolves, our goal is to expand the SSB into a fully curated collection accessible to the public, where community members can both request seeds for restoration projects and contribute seeds from their own collections, fostering a collective effort to protect this species. Following CPC best practices, volunteers in our team are currently conducting storage trials to determine the optimal conditions for preserving saguaro seeds over extended periods. Understanding



Fig. 14 The first and most comprehensive Saguaro Seed Bank. Dry seeds together with dry herbarium material were sent to a partner institution in Durango, México; who have a CITES permit to export dry cactus material to the US. All envelopes managed to arrive well to DBG and now are deposited in the long-term storage at the Seed Bank.

how seed viability changes under different temperature conditions is essential for maintaining a sustainable and effective seed bank. Through these efforts, we aim to establish a permanent conservation resource that not only preserves the genetic legacy of saguaros but also provides critical support for research, restoration, and climate adaptation strategies in the face of increasing environmental challenges.

Saguaro Nursery

A seed bank alone cannot fulfill its conservation potential without an active propagation program. Seeds are only a promise for the future if they are not nurtured into the next generation of plants. However, the DBG lacks the space, resources, and personnel to run a large-scale propagation program for saguaros. To bridge this gap, we launched the *Saguaro Nursery*, a community-based initiative that engages volunteers in growing and caring for young saguaros from diverse genetic backgrounds. This program not only helps preserve saguaro diversity but also strengthens conservation efforts by fostering public participation and education.

Through the Saguaro Census data, we discovered that urban neighborhoods and private yards across the Phoenix Valley play the most important role in maintaining our saguaro urban populations, emphasizing homeowners as the actual stewards of the

saguaros. Unfortunately, rising temperatures and prolonged droughts, particularly in urban heat islands, are impacting saguaros tremendously, contributing to increase their mortality in our cities, thus we are in need of take action and repopulate our neighborhoods with our own hands an initiative. At the same time, our Saguaro Genomics for Conservation Project has revealed that while half of the species' genetic diversity is found in México, those genetic lines are completely missing from urban spaces and conservation collections, including those at DBG. This is where the Saguaro Nursery comes into play. Through this initiative, volunteers germinate and become foster parents of saguaro seedlings for a period of up to three years. They receive germination kits, complete with seeds from different regions and genetic lines, specialized soil, and guidance on cactus care (Figure 15). They become part of a growing network, supported through monthly check-ins, an active listserv (a Facebook page), and periodic community meetings—both virtual and in-person—where participants share experiences and receive advice (Figure 16a-b). Caring for saguaro seedlings is a minimal but meaningful commitment, requiring just ten minutes a week. Volunteers need only a well-lit space, indoors or outdoors, and can reach out for support if they encounter any challenges, such as pests or changing personal circumstances that prevent them from continuing.



Fig. 15 The volunteers joining DBG's Saguaro Nursery receive a kit, which includes a tray, bags with soil and sand, and an envelope with seeds. They sign a foster agreement form, committing to take care and communicating regularly with Saguaro Nursery leads for a period of up to three years.

Genetic research is making it increasingly clear that botanical gardens must radically rethink their approach to *ex situ* conservation. To truly preserve a species, collections must include far more individuals than they currently hold, representing the full spectrum of genetic diversity across the species' entire geographic range. Yet, most botanical collections contain only a handful of individuals per species, effectively preserving only a few genomes rather than the genetic diversity necessary for long-term resilience. The traditional approach is no longer enough—the new era of *ex situ* conservation must prioritize larger, genetically diverse collections while acknowledging the limitations of space, labor, and resources within botanical institutions. At the Hernández Lab, we believe that the future of *ex situ* conservation lies in collective, collaborative efforts, where communities become active stewards of endangered plants. The DBG simply does not have the space, water, or horticultural staff to house the number of saguaros needed to build a genetically representative collection. However, the thousands of residents of the Phoenix Metropolitan Area do. By shifting conservation beyond institutional walls and into urban yards, neighborhoods, and public spaces, we can transform limitations into opportunities—creating an unlimited network of plant stewards committed to ensuring saguaros thrive in an era of climate uncertainty.

Once the young saguaros living in our volunteers' foster homes are strong enough, they will transition into the *Saguaro Adoption Program*. Seedlings will be carefully transplanted to small pots and made available for adoption at the DBG Plant Sale, where members of the public can take home a saguaro and commit to its long-term care. Those who adopt will provide periodic updates, allowing DBG to track survival rates and gain further insights into the success of urban-grown saguaros. This adoption program will extend conservation efforts beyond the Garden while also generating critical funding for ongoing research and initiatives. Through the Saguaro Nursery and Adoption Program, we are not only growing saguaros—we are growing a community of active conservationists. Each seedling represents a tangible contribution to the survival of one of the Sonoran Desert's most iconic species.

The question of whether cacti are dying in the desert is no longer a theoretical concern—it is a reality unfolding before our eyes. The saguaros of the Phoenix Valley serve as both a warning and an opportunity. Their struggle against increasing urban heat and prolonged drought exemplifies the challenges that countless cactus species face across the Americas. But the deep connection between saguaros and the community has also revealed something powerful: **people care, and they want to take action**. Conservation is not just about documenting decline; it is about finding solutions, mobilizing efforts, and redefining how we protect the plants that define our landscapes.

The **Saguaro Initiatives** at the Desert Botanical Garden were born from this urgency, blending scientific research with community-driven conservation to create a model that can be replicated beyond the Phoenix Valley. By engaging the public through programs like the **Saguaro Census**, **Saguaro Dead Report**, **Saguaro Genomics**, **Seed Bank**, and **Nursery**, we are not only gathering the data needed to understand this crisis, but also actively working to safeguard saguaros through reintroduction and stewardship. The survival of saguaros—and cacti as a whole—depends on a shift in conservation thinking (Figure 17). **We cannot rely solely on institutions to safeguard biodiversity; conservation must be a collective effort**. The solutions are in our hands, in our neighborhoods, and in our willingness to redefine what it means to coexist with the species that have shaped the Sonoran Desert for thousands of years. If saguaros are to remain a part of our future, it will be because we made the choice, together, to protect them.

Get involved today!

Figs. 16a–b The Saguaro Nursery is a collective conservation action, where the community around the Phoenix Valley contributes with time and space at home to grow the future generation of urban saguaros. Volunteers kindly lead and coordinate several of these initiatives.



Fig. 16a a workshop where participants assemble their saguaro germination trays and sign their agreements.



Fig 16b from left to right, volunteer Kimberlie Wong, Saguaro Seed Bank lead volunteer Hal Hoover, Dr. Tania Hernández and Saguaro Nursery lead volunteer Crystal Zhou.

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Fig. 17 While in some localities across their range, saguaros struggle, in others they thrive. Here a saguaro forest near Black Canyon City in Arizona.

their unwavering trust and encouragement. D. Swann also offered essential help with saguaro collections. And finally, my heartfelt appreciation goes to A. D. Sanders, my most committed volunteer, sponsor and partner in crime. Thanks to this beautiful community of saguaro lovers that has embraced me so warmly.

References

Goetsch, B., C. Hilton-Taylor, G. Cruz-Piñón, J. P. Duffy, et al. 2015. High proportion of cactus species threatened with extinction. *Nature Plants* 1(10), pp.1–7.

Pillet, M., B. Goetsch, C. Merow, B. Maitner, et al. 2022. Elevated extinction risk of cacti under climate change. *Nature Plants*, 8(4), pp.366–372.

Wilder, B.T., K. R. Hultine, W.B. Dorshow, S. E. Vanderplank, S.E., et al, 2025. Plant responses to anomalous heat and drought events in the Sonoran Desert. *Global Change Biology* 31(5), p.e70217.

[1] Some videos of people recording the collapse of saguaros: <https://youtube.com/shorts/r25MHQ-eFwM?si=9WTzaQYg4XaxASM3>, https://youtu.be/QcA0V3HGdD8?si=_7fEs1LnyfXI4_iH