About This Issue

Dear friend,

This issue marks the Desert Botanical Garden’s renewed commitment to conserving the diversity of Sonoran Desert plant life.

While the Sonoran Desert happens to be our home, it is also world-renowned as a beautiful and unique landscape. Unfortunately, much of it has been abused, degraded or invaded by exotic species. The acreage in undisturbed wildlands and the number of species it harbors is ever-diminishing.

Are there ways to halt these devastating trends, or perhaps reverse them? We can carefully reintroduce threatened species to safe habitats. We can restore native vegetation to areas made barren by human activities. We can also work to preserve remnant wildlands, and remnant traditions which respect the unique flora of our region.

On November 15, 1989, we are presenting these issues to policy-makers, conservationists, and to the media, to offer positive solutions to desert plant rarity problems. We realize that we can’t accomplish these goals alone. Instead, we are joining together with The Nature Conservancy, the Center for Plant Conservation, and the Centro Ecologico de Sonora to work toward tangible accomplishments, not just hand-wringing about problems. We urge you to join with us as well, to heal and nurture our Sonoran Desert homeland.

Sincerely,

Gary Paul Nabhan, PhD.

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Cover: The Desert Botanical Garden research staff has begun to review the vegetation history of the Barnes Butte bajadas in Papago Park, where the Garden was established fifty years ago. Photo by Lynne and Marvin Carlton.
A Modest Proposal:

RESTORING THE SONORAN DESERT AT BARNES BUTTE BAJADA

A saguaro damaged at its base, presumably by jackrabbits, below Barnes Butte. Saguaros damaged in this manner are susceptible to toppling and disease.

by Gary Nabhan, and David Valenciano

DESSERT DEGRADATION PROBLEMS AND RESTORATION ECOLOGY

The area of the world’s drylands which is ecologically damaged every day is equivalent to the 145 acre size of the Desert Botanical Garden in Papago Park. We can literally see and feel the effects of desert degradation immediately around us: the warming-up of the metropolitan Phoenix microclimate at a rate three times as fast as that of adjacent rural Arizona; the denuding of vegetative cover by off-road vehicles and ill-planned hiking or equestrian trails; the illegal removal of cacti and other succulents by unscrupulous collectors; the invasion of exotic weeds onto lands disturbed by overgrazing or agricultural clearance.

The term desertification, used by some scientists as well as the popular press to describe this degradation, unfortunately leaves the impression that deserts are by nature impoverished or depauperate places. In reality, we are losing the diversity, the richness and the health of naturally arid ecosystems, and replacing them with fragmented, dysfunctional shadows of what they once were. While it is imperative that we protect intact the undamaged vestiges of Sonoran Desert which remain extant, we must also come to grips with the problems evident on the more than 400,000 acres of degraded desert which now exist in this region. Particularly rapid land use changes are occurring in the “Coast of Hermosillo” agricultural district and the Valley of Mexicali where salinization is forcing the abandonment of tens of thousands of acres of crop lands. Despite the ongoing efforts to establish sanctuaries and parks to protect virgin desert, the acreage of damaged desert ecosystems evident in the Arizona-Sonora region is likely to double before the year 2000.

It is time to broaden our conservation concerns from preservation alone to consider ways to repair the degraded habitats in our midsts. As Arizona Congressman Morris K. Udall has written, we must “turn our attention to an activity that, with our maturing environmental awareness, we would do well to focus on more intently: restoring the integrity of damaged environments. We can stop the dumping of pollutants into our waterways, but if those ecosystems are not biologically functional and self-sustaining, they are not really healthy. We can set aside the dwindling riparian areas that remain, but
what then of the much vaster ones man has already crippled. Is there not an enormous challenge and opportunity in the possibilities of revitalizing such areas?"


"In restoration, not only are abuses halted, but the resource itself is physically repaired, and, if necessary, its missing components are replaced. Native seed varieties are sown; plants are used to bandage and rebuild the land. Roots, soil, mosses, and fungi all reform a dense living mat of soil that nourishes plants, retains moisture, and cleanses water percolating into the ground. Barrens become productive again. Endangered animal populations gradually revive. While certainly no longer in a pristine state, the restored land becomes healthy, life supporting, and pleasing to the eye."

During this, the fiftieth year since the establishment of the Desert Botanical Garden, it seems timely to review the vegetation history of our site in Papago Park, and to begin careful planning to undo any damage that may have been inadvertently done to its wildlands over the last half century. It has not been much more than a half century since the first intentional ecosystem restoration project began at another botanical institution, the University of Wisconsin/Madison's Arboretum. If we proceed, our restoration of the Barnes Butte bajada may be the first floristic restoration project of its scale in the North American deserts.

INVENTORYING PRESENT AND HISTORICAL CONDITIONS AT BARNES BUTTE VEGETATION

Barnes Buttes is the volcanic breccia landform northwest of the Desert Botanical Garden grounds, and is among the pink-tinted "Papago Buttes" which give Papago Park its international reputation as a scenic attraction. Through the 1910's and 1920's, the area was managed by the National Park Service as Papago Cactus National Monument. One historic photo of the Butte shows roughly three times as many saguaro cacti on the same slope in 1939 as there are visible today. Has this population declined since the time the Garden was established nearby, fifty years ago? Have other plant species changed in abundance?

Using a variety of plant ecology techniques, the Desert Botanical Garden research staff began to assess the present-day structure of plant populations on the southern reaches of the Buttes bajadas, 16 acres of which is managed by the Garden (Figure 1 & 2). Our preliminary estimate is that only one of the 45 saguaros on the southern bajadas of the Buttes is under 50 years old! Using saguaro height to age class conversion tables developed for an area of rainfall comparable to our own (Organ Pipe Cactus National Monument), we have determined that over 85% of the
and susceptibility to frost damage, we hypothesize that the Barnes Butte saguaro population has lost many of the previously established individuals to herbivore damage. Saguaros too young to form thick callouses at the base become extremely vulnerable to rabbits. Our current saguaro population may be “missing” size classes that would be evident were rabbit populations less dense.

It is difficult to factor out climatic influences from man-caused ecological influences with respect to changes in any local environment. Nevertheless, one hypothesis we are currently entertaining is that the Barnes Butte bajada has suffered a saguaro decline over the last few decades due to a human-aggravated jackrabbit population explosion in Papago Park (Figure 4). The Phoenix Zoo, the golf courses and the Garden all offer artificially-watered greenery to jackrabbits and cottontails. As their populations increase in these artificial oases, they “export” their surplus numbers to surrounding areas in Papago Park, where forageable plants are few and far between. Less palatable species, including little-leaf palo verde and saguaro, now suffer the pressures of herbivory. Our census data show that surviving palo verde seedlings are isolated to just a few marginal patches on the Butte bajada. Saguaros are also indirectly affected by the paucity of palo verdens on the study site, since these trees are the common nurse plants under which saguaro seeds are typically dispersed, germinated and established.

In a natural desert ecosystem, rabbit populations would be regulated by predators such as coyotes or raptors. Coyotes, unfortunately, have been largely removed from Papago Park through decades of trapping or by falling victim to the automobile. Other predators, less tolerant of human presence, have fled the park as housing developments encroached upon its boundaries.

Additional historic land uses have affected the flora of the Barnes Butte bajada. Sheep once grazed much of Papago Park. Cholla cactus were removed from it by government-subsidized cacti laborers. Poachers have dug up smaller clumps of cactus to take home as mementos of their visits to the park. Hikers and dirt bikers ovemse certain trails, accelerating erosion and widening barren areas.

Fortunately, Barnes Butte keeps “its own record” of the plant species which formerly inhabited its flanks. In the form of packrat middens, this fossil record includes fragments of fruit, seeds, spines and twigs which formerly grew within 100 yards or so of the rock crevices to where the packrats brought their plant samples. Dr. Pat Fall of the Arizona State University Department of Geography is advising Garden researchers on the identification and interpretation of these fossils, to determine if we have “lost” any species from the Butte flora over the millennia. Plant fragments from the last few centuries can provide us with an idea of which locally-extirpated species may be suitable for reintroduction to the Buttes bajada today. From the foregoing discussion it is clear that the Buttes have suffered from degradation of their vegetative cover, and that we feel an obligation to remedy this situation.

FLORISTIC RESTORATION OF THE BUTTES BAJADA

Using as our guides packrat middens, early botanists’ notes, herbarium specimens and photos, it may be possible for us to enrich the present Barnes Buttes flora to its former diversity. However, it is not merely enough to transplant the “missing species” and expect the ecosystem to fully recover. To insure the long-term persistence of saguaros and fishhook cacti, it may be necessary to re-establish higher numbers of palo verdens, ironwoods and cholla to serve as protective nurses. Bursage and creosote shrubs, in turn, serve as nurses for seedlings of trees, shrubs and succulents. If bursage and creosote cover has decreased, and continues to do so, safe sites for other species may be lacking. Maintenance and protection of shrub cover may involve the control of rabbit populations through fencing enclosures, feeding deterrents or predator reintroductions. (Does anyone know a coyote or falcon for hire?)

Over the next two years, a grant from the Jesse Smith Noyes Foundation will allow us to initiate restoration of the Barnes Butte bajada, and of several abandoned agricultural areas in central Arizona. In each case, we will attempt to carefully assess the existing flora and historic records before beginning directed changes. Local seed sources for transplants will be utilized rather than exotic gene pools. Innovative techniques will be applied for re-establishing low-water-requiring shrubs and cryptogamic soil crusts. An interagency task force on desert restoration will advise us in our efforts, as well as informing us of their own successes in similar projects (next page). Hopefully, our promotion of these model desert restoration projects will encourage others to try healing damaged dryland ecosystems. It is hopefully not too late to start; the fate of the earth may depend upon efforts such as these.
DESSERT RESTORATION TASK FORCE

Many of the current efforts toward restoring degraded habitats are located in coastal, subhumid grassland or forested areas. Projects in North American desert regions are few in number, and are largely restricted to riparian corridors and mined lands. There is a great need among parks, nature reserves and wildlife refuges to restore degraded areas within their boundaries to vegetative cover approaching that of natural plant communities.

To remedy these imbalances, the Desert Botanical Garden has recently invited experienced individuals and agencies to participate in the first Desert Restoration Task Force ever assembled anywhere in the world. Going beyond conventional land “reclamation” objectives, restoration ecologists seek to use locally native plants and microorganisms to rehabilitate damaged areas to their former structure and function. Task force participants have already been involved in seed collection and evaluation; revegetation of barren areas; restoring degraded deserts to an earlier condition; analyzing vegetation change; experimenting with low-cost techniques for plant establishment in the field; restoring or creating wildlife habitat with native plants; and recovering abandoned fields. We welcome others to participate in the task force. We are honored to initially include the following resource managers in the Desert Restoration Task Force:

Rita Jo Anthony, Wild Seed, Inc., Tempe, AZ
Kevin Dahl, Native Seeds/SEARCH and Arizona Native Plant Society, Tucson, AZ
James Barnett, Organ Pipe Cactus National Monument, Ajo, AZ
Guy McPherson, School of Renewable Natural Resources, University of Arizona, Tucson, AZ
Jayne Belnap, Canyonlands National Park, Moab, Utah
Bruce Roundy, Range Management, University of Arizona, Tucson, AZ
Robert Dixon, The Imprinting Foundation, Tucson, AZ
Martin Karpiscak, Office of Arid Lands Studies, University of Arizona, Tucson, AZ
Tim Murphy, Sonoran Permaculture Services, Tucson, AZ
R. Mitchel Beauchamp, Pacific Southwest Biological Services
Joel Glanzberg, Flowering Tree Permaculture Institute
Liz Ecker, Desert Botanical Garden

Long Term Maintenance of Desert Diversity: Rare Plant Reintroductions by Liz Ecker

The rapid extinction of many plant species due to widespread destruction of tropical rainforests has been widely publicized. Globally, desert habitats are being converted to agricultural and urban lands on a scale which perhaps surpasses the conversion rates in the wet tropics. This conversion and/or degradation of dry lands is estimated to affect 6 million hectares annually, with the net result being that many desert-adapted plants are being lost from natural areas altogether. Degradation, or loss of habitats in temperate and arid zones in the United States has resulted in the extinction of more than 200 of our native American plant species (Falk and McMahan 1988). An additional 680 taxa may become extinct within the next 5 to 10 years if measures are not taken (Center for Plant Conservation 1988).

In an effort to curb extinction, many rare plants have been rescued from their threatened natural habitats and maintained in various types of cultivation, termed “ex-situ” conservation. However, most authorities agree that maintaining plants within their natural habitats with the cultural and ecological requirements a plant evolved with is preferable to “ex-situ” conservation.

Plant reintroduction is one method which is aimed at preserving plants “in-situ,” and involves the placement of salvaged or propagated rare plant material back into native habitats where the species has become extinct or endangered. Although reintroduction seems a very simple and logical solution to the problems rare plants face, many instances of less than desired results have been obtained when plants are reintroduced. Through the continued research of rare plant species and reintroduction programs at the Desert Botanical Garden, we have developed several guidelines which may improve the success rates of rare plant reintroductions.

There are two major areas that must be thoroughly assessed prior to implementing a rare plant reintroduction: the ecology of the plant in question and the horticultural practices which will promote adjustment of the plant back into habitat. Clearly, these two factors seem obvious; however, oversights of ecological and horticultural factors have contributed to low success rates in many plant reintroductions. In addition, success in rare plant reintroductions is measured not only by high survival rates during the difficult transplant period, but also by the ability of the reintroduction population to maintain vigor and adaptability over the long term, or ecological time (Soule 1987).

PLANT ECOLOGY

The most critical information to obtain when planning a reintroduction is accurate baseline ecological data on the species in question. Knowledge of a plant’s habitat and how it functions within the ecosystem is vital to reintroduction success. Observation of a rare plant in habitat for a minimum of a year, if possible, is important so that data can be collected about the behavior of the plant during the growing season, flowering and fruit set period, as well as the dormant season. It is important to study rare plants in habitat first, as plants kept “ex-situ” may often exhibit very different behavior versus that of plants in native habitats. Habitat assessment should include careful analysis of topography, slope, elevation, climate, plant community and associated plants. Soil studies are often overlooked, but may be quite important to long term survival, that is, reproductive ability. For instance, although Thornier’s fishhook cactus (Mammillaria thornii) may be able to survive in various soil types, a gravelly surface soil texture appears to be an important factor for seedling germination (McLaughlin 1987).

Choosing the proper habitat for a rare
Plant reintroduction is important, but the actual key to habitat selection is a complete understanding and examination of the micro-habitat a plant grows in. Many desert plants have nurse plant associations that require extensive investigation before a reintroduction is attempted. Does the plant require a nurse plant or does it serve as one? Is there a particular nurse plant species more commonly associated with the rare plant in question than other plant species? Does the nurse plant serve to protect the plant from harsh environmental conditions, herbivory, act as a source of mycorrhizal inoculum, or all three? Is there a particular exposure beneath the nurse plant more common? What light intensity readings are obtained beneath the canopy? Thornber’s fishhook cactus is almost always found beneath nurse plants, and preliminary evidence with experimental plantings at the DBG of cacti grown in the open versus those grown under nurse plants has shown high mortality and decreased growth in plants growing in the open. These results, coupled with the fact that open plants have had continued mortality well into the second year since transplant, suggest the shade provided by the nurse plant is critical to this cactus species survival.

Recent evidence has shown that many desert plants form symbiotic associations with mycorrhizal fungi. In return for photosynthates the mycorrhizal fungus derives from the host, it may benefit the host plant by increasing plant growth due to the fungus’ ability to increase absorption of phosphorus and other elements, and decreasing resistance to water stress. The adaptive significance of mycorrhizal symbiosis in the Sonoran Desert is apparent as lack of water and available nutrients are two major factors which limit plant survival and growth. Therefore, root samples of rare plants should be obtained and stained to determine if mycorrhizae are present. Two rare cacti of Arizona, Thornber’s fishhook cactus and the gramma grass cactus (Toumeya papyracantha), have both been documented to have mycorrhizal associations, and this may prove critical to success in future reintroduction programs with these species.

Long term success of reintroduced populations requires the ability of plants to reproduce. Careful study of the pollination and reproductive biology of a rare plant within habitat is, therefore, important. Determination of pollinators, pollinator foraging behavior and the presence of these pollinators in a potential reintroduction habitat should be made. The plant’s breeding system, flowering period, age of maturity, length of reproductive life and method of seed dispersal also require study. The importance of thorough reproductive biology studies can be illustrated by recent work carried out by the DBG on the rare Arizona agave (Agave arizonica). This agave has been found to require outcrossing, or pollen from a different plant, to reproduce viable seed. Future reintroductions done with this plant will require individuals or “pups” from different mother plants in order for sexual reproduction to occur.

Determination of a plant’s pollination mechanisms and ability to reproduce is important, but to be viable over the long term, a population must be able to adapt. Therefore, provision for genetic variation in reintroductions is important. This can be provided for by collecting rare plant material chosen from different sites within a population, with differing morphologies, and from outlying areas of a population. Caution must be exercised when providing for genetic diversity, however. Mixing genes of one population with that of a very distinct, different population may interrupt co-adapted gene complexes of the former population, and can lead to extinction in small populations (Noss 1987). Generally, if two populations are genetically distinct, genetic transfer should be avoided (Ledig 1987). Genetic differences can be examined by a method termed “isozyme analysis,” and this method may be used in cases where population numbers are low and use of immigrant plants is a consideration.

**HORTICULTURAL FACTORS**

Once the ecology of a rare plant is fully investigated, careful horticultural application of ecological data is important for successful reintroductions. Site selection, along with micro-habitat choice, are the most critical factors that should be considered horticulturally. The reintroduction site should be within historic habitat or very near, if possible. This generally helps to avoid such problems as introduction of unadapted genetic complexes, lack of pollinators, improper soil types and climatic problems. Micro-habitat requirements should also be closely matched. Planting sites should provide proper nurse
plants, slope, exposure, etc. Soil samples should be obtained from under an existing rare plant if available, so that soil texture, ion concentrations and any other specific soil characteristics can be provided for in the reintroduction planting site. Germination site requirements must be present. Fencing is usually needed to prevent herbivory and vandalism. Finally, the reintroduction site should be relatively inaccessible so that collectors and those of a destructive nature will not undo your work.

If a rare plant has been salvaged and determined to have mycorrhizal associations, it will have the fungal symbiont for its lifespan. Consequently, care should be taken not to apply fungicides during collection or “ex-situ” maintenance. Propagated material, however, will not have mycorrhizae. Studies have shown that plants which were pre-inoculated before being transplanted had increased survival, growth, and reproductive output (Zajicek et al. 1987, Biermann and Linderman 1983). This is thought to be due to the fact that new roots may be colonized more readily from mycorrhizae existing on older, pre-existing roots than from mycorrhizae existing in the native soil (Biermann and Linderman 1983). This suggests that in reintroductions rare pre-inoculated propagated plants may have increased survival and growth versus non-inoculated plants. The DBG is currently conducting survival and growth experiments on non- and pre-inoculated Thomber’s fishhook cacti seedlings.

Fungal cultures for inoculation should be grown from spores obtained from habitat so that foreign mycorrhizae are not introduced (they also may not be as effective). High phosphorus levels will inhibit penetration and growth of mycorrhizae, so low phosphorus fertilization levels are important. In addition, soilless media generally inhibit mycorrhizae growth; therefore, sterilized sand or soil should be incorporated into the medium.

Cultural treatment of rare plants while in an “ex-situ” environment is very important. The best success in reintroductions has been achieved when the actual habitat conditions are simulated as closely as possible while the plants are maintained “ex-situ.” Light intensity, water and fertilizer should be provided throughout the year at levels similar to occurrence in habitat. A special note should be made about water and fertilizer. Lush growth produced from ample fertilizer and water may produce lovely plants; however, this growth cannot usually be supported in habitat. Thomber’s fishhook cacti in habitat had an average stem number of 10 stems per plant when they were salvaged. These same plants after being given optimal water and fertilizer for 2 years in the greenhouse had an average stem number of 20. After being reintroduced, a large percentage of stems died on most plants. In the competitiveness of a natural system, these cacti were unable to support their excessive growth and clump size, and responded to stress by selective death of stems. Based on these results, we are currently fertilizing propagated Thomber’s fishhook cacti at levels of 25 ppm N, 4 ppm P and 12 ppm K. These levels allow for growth, but prevent excessive clump size.

Mature plants which have been grown as close as possible to habitat conditions will require little “hardening off” before the actual reintroduction transplant. However, native conditions cannot always be simulated exactly, and propagated material may require a “hardening off” period. Fertilizer should be withheld at least one month prior to transplant, and avoided at transplant. In a reintroduction of *Amsonia kearneyana* 20% mortality was obtained, most probably due to fertilizer burn caused from a handful of ammonium sulfate being placed in the bottom of the planting hole (Reichenbacher, personal comm.). Light and water should be increased or decreased, depending on the conditions at the reintroduction site during the time of year the transplant is carried out.

The season a reintroduction is transplanted is another important horticultural aspect of reintroduction programs. One method is to decide which season of the year is most stressful on the plant (for example, summer would be most stressful on most Sonoran Desert plants), and then plant after that season (for example, in the fall, giving the plant the longest time period to adjust). However, seasons can be unpredictable, and transplanting a group of plants in both spring and fall may be a safer method to better evaluate potential problems and avoid major losses.

At the time of transplanting, actual individual planting sites should be chosen based on ecological data to provide for the proper microhabitat. Watering is generally required to help settle the soil around the root system; however, species-specific requirements should be kept in mind. If watering, it is important to prevent damage to root systems so that soilborne pathogens do not have pathways to enter and infect plants. Plants which are to be bare root planted should have soil gently shaken away from the root system. It has been found that in both reintroduction and revegetation projects that lack of a proper post-transplant monitoring program is most often related to failure (Hall 1987). Frequent visits immediately after transplanting are needed to evaluate water requirements, plant adjustment back into habitat, herbivory, disease, or other potential problems. Thomber’s fishhook cacti still required watering six months after transplanting due to an extremely cold winter in which root growth into native soil was very limited, followed by one of the hottest, driest springs on record in Avra Valley. In addition, a control population is important to establish, if possible, for comparison and observation.

Many factors, both ecological and horticultural, must be analyzed when attempting reintroductions of rare plants. As natural areas continue to be lost and fragmented, many native plants may increase in rareness and require salvage. The DBG team approach to reintroductions using botanists, horticulturists and plant ecologists will provide the increased skill needed to help maintain one of our rarest natural resources, the unique flora of the Sonoran Desert.

REFERENCES


Prehistoric Fields in Central Arizona:

CONSERVING REDISCOVERED AGAVE CULTIVARS

by Wendy Hodgson, Gary Nabhan, and Liz Ecker

It is well known that the genus Agave has provided food, fiber, and beverage to indigenous farmers in Latin America since prehistoric times. Possible cultivation by preColumbian cultures in the U.S. Southwest has long been hypothesized; there now exists strong evidence of prehistoric agave cultivation in central Arizona. Yet the evidence — surviving domesticated agaves and their archaeological contexts — are currently threatened. Desert Botanical Garden researchers are leading renewed efforts to study and conserve these important remnants of our American agricultural heritage.

In 1935 Frederick Gibson, then director of the Boyce Thompson Arboretum in Superior, Arizona, described an unusual agave species first observed by amateur naturalist William C. Murphey. Murphey discovered this agave growing on hills near Queen Creek, just outside of Superior at an elevation between 2000 and 2500 feet (Gibson, 1935). Propagated offspring of the Queen Creek clone has become a popular ornamental in Arizona. For years, the only other known clones were seen at Roosevelt Dam, Paradise Valley, and Tonto Basin, an area known for its impressive cliff dwellings and rich archaeobotanical remains. A few other populations were later found several hundred miles away in gardens in Sells and Topawa on the Tohono O’odham Reservation, at O’odham villages in adjacent Sonora, and as ornamentals and sources for mescal liquor in several ranches near Caborca, Sonora.

This relatively simple story was soon to change. In February, 1988, Desert Botanical Garden research assistant Rick DeLamater brought to our attention A. murpheyi clones near a prehistoric village site in the New River watershed. In that watershed, he established the presence of more than 20 clones, four times as many as have been cumulatively documented elsewhere to date. With other Garden staff, it was discovered that near New River, some of these clones persisted in Hohokam agricultural fields abandoned five to six centuries ago. We now know of 30 sites within the Bradshaw Mountains, New River and Agua Fria drainages, and Tonto Basin. All sites are in association with Hohokam and Salado archaeology. Most A. murpheyi clones are associated with basalt cobble alignments or terraces, which run up to 50 feet in length (which functioned to catch and direct storm runoff), rock piles (to catch and retain moisture and soil nutrients), and high concentrations of stone tools (such as turtleback scrapers and mescal knives to harvest and process agaves).

While these were the first discoveries of living agaves in an archaeological context, Charles Miksicek had earlier identified agave fibers in flotation samples for prehistoric Hohokam sites. Shortly after Miksicek’s 1982 archaeobotanical find, extensive agave cultivation in southern Arizona was deduced from the strong association of roasting pits and mescal knives with rock piles and check dam features covering tens of thousands of hectares of desert bajada slopes (Fish, et al., 1985). A terminal spine and marginal teeth recovered from several sites in the same area (Fish, et al., 1985) and tissue fragments from La Ciudad (site of present day Phoenix) excavations (Bohrer, 1986) have been tentatively identified as A. murpheyi, but diagnostic characters are usually absent from archaeological agave remains.

Ethnographic evidence suggests that Agave...
*Agave murpheyi* was valued for food and fiber. It may have been extremely significant in terms of the cultural heritage of indigenous people in the arid borderlands region, both prehistorically and historically into relatively recent times. *Agave murpheyi* displays characteristics which suggest that it is a domesticated or culturally-selected species:

1. initiates inflorescence (flower stalk) development in the winter (as no other Arizona agaves do),
2. produces large "heads," or leaf base/caudex biomass for food,
3. produces hundreds of bulbils (small plantlets) on the flower stalk, which root only in disturbed soil,
4. offsets profusely,
5. sets no fertile seed,
6. has a short maturation time,
7. has teeth on leaf margins which are relatively unobstrusive,
8. has leaves which are easily cut, and
9. produces less caustic juice (which may irritate one's skin) in the leaves when compared to other agaves.

The inflorescence of *A. murpheyi* begins to elongate in late winter, much earlier than other Arizona and Sonora agaves. Among southwestern Indian tribes, agaves were typically harvested prior to, and during stalk emergence, because that is when the plants begin translocating sugars to above-ground parts. The heads of *A. murpheyi* are relatively large and provided considerable food for the amount of time and energy spent growing, harvesting, and processing. Roasted heads may have provided the first sweet, juicy produce following a winter period of dried and stored foods. Plants may not have been limited to local use, but were probably a major trade item for both food and fiber, as other agave species were historically among desert tribes.

Cold temperatures may retard inflorescence development of *A. murpheyi* until warmer temperatures return. Freezing temperatures may damage inflorescences. This could have little, if any, effect on the harvest of its heads since they were collected just prior to stalk emergence. Flowers are produced but abort, and are replaced by vegetative bulbils. Hundreds of bulbils are produced on one inflorescence and establish quickly when tended. In Quitovac, Sonora, the O'odham call the plant *non-hokam*, meaning "it has eggs, or progeny," referring to the bulbils. Bulbils still attached on the inflorescence could be transported from one habitation site to another with ease. However, the principle method of reproduction may have been the profuse development of clonal offshoots, arising from rhizomes at the base of the parent plant. No fertile seed is produced.

With supplemental water, *A. murpheyi* can mature in less than ten years, whereas maturation time for most agaves, including the smaller species, can be 20 to 50 years. The life cycle has also been shortened in tequila agaves, which now mature in four to six years. The leaf margins of agaves often produce a formidable armature of large, recurved (hooked) spines. The teeth on leaf margins of *A. murpheyi* are relatively small and straight, not recurved. Turtleback scrapers easily peel the teeth off leaf margins of leaves to be used for fiber. In addition, the leaves of *A. murpheyi* are relatively easy to cut at their base using a *mescal* knife. Finally, unlike most other agaves, *A. murpheyi* does not have as caustic a juice within the leaves and leaf bases as many other agaves and are thus easier to handle.

It seems clear that this species was domesticated by prehistoric Indians, perhaps through repeated selection of somatic mutants displaying such desirable characteristics. Unfortunately, this native domesticate of the Sonoran Desert has persisted only in a few O'odham villages and around a few prehistoric field sites, some of which were abandoned more than 500 years ago (Nabhan, et al., 1988). The agave fields at Table Mesa, New River Mountains, are the first documented prehistoric Indian fields in the U.S. where a remnant, relictual crop plant persists *in situ* in association with runoff harvesting technologies and processing tools of American farmers (Delamater, et al., 1989). The extent of *A. murpheyi* cultivation is unknown but may have covered more than 10,000 acres of Arizona lands by the prehistoric Hohokam between 500 A.D. and 1400 A.D. The Table Mesa site was the first unchallengeable record...
of pre-Columbian cultivation of mescal north of Mexico. Yet, areas where the plant formerly grew have been cleared and converted to homes and businesses in metropolitan Phoenix and suburbs where impending growth continues to be a threat. Planned expansion of Lake Pleasant and Roosevelt reservoirs will impact existing clones within the increased capacity expansion area.

As a result of surveys during the past two years in Tonto Basin, Gila County, we now have strong evidence that the Hohokam also cultivated an additional agave, which we are tentatively calling *A. "tontobasinsensis"* species nova. A number of sterile clones of *A. "tontobasinsensis"* were discovered by Rick DeLamater during the course of one week. To date, we know of 45 sites and all are associated with an impressive amount of archaeological features including basalt cobble alignments, rock piles, multi-roomed foundations, *mescal* knives, and turtleneck scrapers. The majority of sites are found on mesa tops, on the edge of southwest-facing slopes overlooking drainages. The marginal teeth of archaeological agaves recovered in the Tucson Basin approaches that of *A. "tontobasinsensis,"* although they were identified as *A. parryi* at that time by Fish, et al. (1985), since this new species had not yet been reported.

Laura Kerman, an O’odham woman, reminisced to us how her family used to live winters in a particular canyon in the Baboquivari Mountains. There, she claimed, they formerly harvested *A. murpheyi* for food, called “food-'a'ed” and another large unidentified agave for fiber, called “rope-'a'ed” (*'a'ed* is the O’odham name for agave). Like the O’odham, could the Hohokam have used and possibly cultivated two (or more) different kinds of agave, used for different purposes, e.g., food and fiber? Although *A. "tontobasinsensis"* does not produce bulbils on undamaged flower stalks, it produces offsets vigorously. Like *A. murpheyi*, this agave could have been transported easily via its offsets through migrations or trade.

An incredible story of prehistoric and historic agriculture might be reconstructed if we legally protect and study these plants, which are both natural and cultural resources. To date, however, *A. murpheyi* and *A. "tontobasinsensis"* are protected only by the Arizona native plant law. We have proposed *A. murpheyi* for Threatened Species status under the Endangered Species Act, and have initiated steps in nominating the Table Mesa agave fields for the National Register of Historic Places. We have also sought protection for these species in their archaeological contexts through the State Historic Preservation Office, which has agreed to enforce the Antiquities Act and Historic Preservation Act with regard to those prehistoric artifacts. In addition, DBG has convened and now chairs an interagency task force on Prehistoric Agave Resources which includes the Bureau of Reclamation, U.S. Forest Service, U.S. Fish and Wildlife Service, Arizona Game and Fish Department, Historic Preservation Office, and State Museum scientists. We will soon describe the Tonto Basin agave as a new taxon and will propose for it special status designation.

**LITERATURE CITED**


morexia, or saiy, is one of the better kept secrets of the southwestern plant world, its beauty and usefulness being known to relatively few fortunate people. Virtually all parts of the plant were formerly used as a food item, including the roots, young leaves, flowers, fruits, and seeds (Hodgson, in press). Yet one of the species is quite rare, and up until my efforts began, this rarity had been overlooked by the conservation community. Our work with these species shows how the conservation of ethnic plant lore can be linked with the conservation of the gene pools of useful plants.

In Arizona and Sonora are found two species of saiy, A. palmatifida (found in southern Arizona and extending south into Central America) and the apparently very rare A. gonzalezii. Due to usually inadequate herbarium specimens, the true picture of utilization and distribution of A. gonzalezii is unclear. The roots of both species provide a once important food source to various southwestern people. To a Seri band inhabiting Tiburon Island, the roots of A. palmatifida were especially important (Felger and Moser, 1976, 1985). The tuber-like root was dug with a stick, then eaten raw, boiled with meat, or toasted lightly in the fire, savored with honey, mule dear, or turtle fat. The uncooked root is said to taste like jicama (Pachyrizus spp., the jicama found in supermarkets). The flowers and tender young fruit were also eaten by the Seri and may be cooked with deer fat and bones. “Bark” from the root was cooked like beans with fat. Thin slices of root were often strung as necklaces. When walking in the desert, a mother sometimes gave slices of the strung, dried root to her child to eat.

Saiya provided an edible root for the Arizona O’odham and Pima (Palmer, 1878, cited as A. scheideanana; Havard, 1895; Poppendieck, 1981). The roots were roasted or baked in hot ashes. It was considered quite palatable, with a slightly bitter tang, the taste comparing favorably to carrot and parsnip.
Jatropha macrorhiza (G. Nabhan, pers. comm.). Those who inadvertently did suffered for days from diarrhea.

The Yaqui also ate the roots of saiya, the taste considered by Edward Palmer to be that of parsnip and carrot (Watson, 1889). Yaqui survivors of the 1890’s battle with the Mexican government sought refuge in the Sierra Bacatate and elderly Yaqui still revere the plant when shown it (Gary Nabhan, pers. comm.). Here they survived largely on mesquite and boiled, or preferbly, roasted (Gentry, 1963). According to Maria Bartran, temaqui (saiya) roots are still eaten about Guasabes and Granados, Sonora.

At the time of his writing, Aschmann (1959, pp. 88-89) observed that the people in Baja California still utilized the roots:

The roots of this plant are still collected from the clayey soils, often mixed with rock fragments, which form on hilltops, relatively level basalt surfaces in the mountainous central part of the peninsula as far north as San Borja, though the plants are much more abundant near Mission Guadalupe. The plant sprouts after summer rains and dies back in the fall. The edible tubers can be collected at any time through the following spring, and the modern inhabitants of isolated mountain ranchos are very adept at finding the tubers when only a bit of dry stalk can be seen. The tubers are about the size, shape, and texture of a small parsnip. They are commonly boiled or roasted, though they can be eaten raw. Today each family eats several pounds per year, gathering the tubers from a few special plots, some in quite remote spots visited in connection with herding or hunting activities. A traveler along a burro trail will recognize such plots, and will often dismount and dig in the stony clay until he has collected a pound or two of roots.

Amoreuxia gonzalezii appears to be a very rare plant, at least in Arizona. In the United States it is known with certainty from two locations in the Santa Rita Mountains, Pima County, on limestone foothills, growing with A. palmatifida. The U.S. Fish and Wildlife Service now considers this saiya as a Category 2 taxon1 and the U.S. Forest Service includes it on their sensitive species list.

In Mexico the plant is known from only seven to nine localities. Brandegee (1901) collected an Amoreuxia in the Cape Region of Baja California, which based on his description, fits very well with A. gonzalezii, a species described 21 years later from a plant collected in Chihuahua, Sinaloa. Brandegee’s collection may be the first and only documentation of the species for Baja California, although not listed in Wiggins (1980). It remains to be known if it was ever in great enough quantity for food exploit or even used incidentally.

Penington (1980) stated that the roots and bolitas (fruit) of a saiya, cited as A. gonzalezii, are boiled for food by the Lower Pima at Onavas. The roots of A. palmatifida were also collected and prepared this way. It’s not known if the Pimans had two different names for the two saiyas is unclear although one might assume their ability to differentiate between the two. Despite the difficulty in distinguishing A. gonzalezii from A. palmatifida in a sterile condition, it is easy when plants are in flower and even easier when in fruit. Flowers of A. palmatifida are deep salmon-orange with anthers that are all purple. Flowers of A. gonzalezii (based on a few collections) are pale salmon with the lowermost anthers cream-colored and the upper anthers purple. The tapered fruits with globose seeds of A. gonzalezii compared to the more rounded fruits with kidney-shaped seeds quickly sets the two apart in the field. Amoreuxia gonzalezii was recently collected near Onavas (Amadeo Rea, s.n. DES). Pedro Estrella, an Onavas Piman informant, told how he and others of his community frequently harvested this plant for its roots in the past, the primary area of harvest at a graphite mine site. Today, Señor Estrella says he and his people harvest the plants only incidentally (Amadeo Rea, Gary Nabhan, pers. comm.). Señor Estrella’s knowledge of the rare saiya represent valuable information from indigenous people concerning rare plants which is usually overlooked. More often than not, conservation biologists are unaware that native people may have detailed knowledge about particular rare plants which grow in the vicinity of their homes (Nabhan, et al., 1988).

To date only one endangered species recovery plan in the U.S. has included ethnobotanical data on the species from local people, and it recommends local (Navajo) participation in habitat protection and plant population recovery (House, 1987).

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Seeds of both saiyas are so difficult to germinate ex situ that I wonder how either type of saiya is so successful in the wild. Good production of flowers and fruits appear dependent on adequate summer rains. With little precipitation few fruits from very depauperate plants are produced. Flowers are often subjected to insect and ungulate herbivory. Señor Estrella says cattle eat the fruits of A. gonzalezii near Onavas, Sonora. Even on moderate to lightly grazed areas, livestock, which relishes the tender, juicy immature fruits and seeds, consume the majority of fruits, thereby decreasing potential seed set. I have located populations of both species of saiya in southern Arizona and northeastern Sonora in flower. Upon revisiting these same populations two to three weeks later few, if any plants were found. Another possible threat to the survivorship of either saiya, particularly the less common A. gonzalezii, is the introduction of buffelgrass, Cenchrus ciliaris (Hodgson, in press). This aggressive and most successful grass was introduced to Sonorans by Texas range scientists for use as a forage plant for cattle. Thousands of acres, once habitats to cardon cacti (Pachycereus pringlei and P. pectinaboriginum), morningglory tree (Ipomoea arborescens), and organpipe cacti (Stenocereus thurberi) are now a sea of buffelgrass. How saiya is competing with buffelgrass is not known.

Additional research on seed germination requirements, nutritional composition, and more intensive field work with better, more complete herbarium specimens of Amoreuxia palmatifida and the rare A. gonzalezii is necessary. At the Desert Botanical Garden we are actively involved in field surveys for A. gonzalezii and have had fairly good success at germinating both saiyas At the University of Sonora, research is being conducted to study saiya’s usefulness as an economic food plant. Both the Garden and the CICTUS research branch of the University of Sonora are maintaining germ plasm of these species in seed banks so that their gene pools can be at least partially conserved.

1It represents a taxon for which information indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data are not available to support proposed rules at this time.
Plants at Risk in the Sonoran Desert: An International Concern

Introduction by Gary Paul Nabhan

The following list of plant species at risk is the first ever published for the binational Sonoran Desert. It has benefited from the work of botanists working in institutions on both sides of the border. No binational conservation collaboration could ever be more appropriate, because some rare plant populations, such as those of the two night-blooming cereus species, literally depend on pollen flow across the border to sustain their numbers. In addition, new geographic delineations of the Sonoran Desert have clarified that it is the one North American desert cut nearly in half by the international boundary. If we worry about rare populations on one side of the border without concern for those on the other, we may be missing half the story!

The Sonoran Desert, as we define it today (see map), is a cohesive ecological region divided almost fifty/fifty by the political boundary between the U.S. and Mexico. On the basis of McLaughlin’s (1989) comparisons of the floras of western U.S., some of the Mohave Desert should be considered a subregion of the Sonoran Desert, rather than an entity of equal distinctiveness to the Sonoran. On the basis of climatological analyses by Schmidt (1989) and others, Shreve’s (1951) inclusion of the subtropical foothills of Sonora subregion in the Sonoran Desert is inappropriate, so that much of eastern Sonora falls outside the Sonoran Desert region. The combination of these two changes in definition gives us a Sonoran Desert region more equally divided between the two countries, with the following states being represented: Arizona; California; Nevada; Sonora; Sinaloa; Baja California Norte and Sur. The lowest precipitation totals, and the highest nighttime temperatures in North America occur in the Sonoran Desert (Schmidt 1989).

Despite the extreme aridity of this region, it is well-known for its diversity of lifeforms (Shreve 1951) and for its fantastic endemic plant species, the most infamous being the...
boojum, *Fouquieria columnaris*, of Baja California and Sonora. Unfortunately, where showy plants have restricted ranges, there is a high probability that collection pressure or poor land management practices can rapidly deplete plant populations. Although the Sonoran Desert has not suffered from as extensive illegal collection of rare cacti and succulents as has the Chihuahuan Desert, certain areas remain vulnerable to illegal plant collecting by both amateurs and professionals. Surprisingly, National Park Service biologists have discovered that a higher rate of illegal removal of cacti from lands managed for “conservation” than on lands managed for other uses, because national parks and other highly scenic conservation-oriented areas concentrate tourists who are willing to take illegal souvenirs (Bennett, Johnson and Kunzman 1987). As a result, one cannot consider endangered plants to be safe even within a national park, nature conservancy area or botanical garden explicitly devoted to plant conservation.

Yet, overcollection is not the only pressure on rare plants. Overgrazing, vegetation conversion to exotic forage species, land clearing for urban and agricultural development, mining, pesticide use, off-road vehicle use and firewood cutting all directly or indirectly affect rare or restricted species. We call these species “plants at risk” in this list to include any species of concern, not merely those protected by federal laws or CITES at present.

This list is a preliminary survey designed to stimulate more research, discussion, revision and conservation. We are currently working on a similar list for all borderlands states. We encourage your comments, observations and participation in safeguarding these plants.

**BIBLIOGRAPHY**


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### A PRELIMINARY LIST OF PLANTS AT RISK IN THE SONORAN DESERT OF THE U.S. AND MEXICO

**Gary Paul Nabhan, Esther Saucedo Montague, Peggy Olwell, Peter Warren, Wendy Hodgson, Carlos Gallindo Duarte, Roxanne Bateman and Susan Anderson**

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Barnes Butte's has a fossil record of the plant species which inhabited its flanks. Packrat middens include fragments of fruit, seeds, spines and twigs that grew within 100 yards of the rock crevices where the packrats brought their plant samples.