Desert Plants

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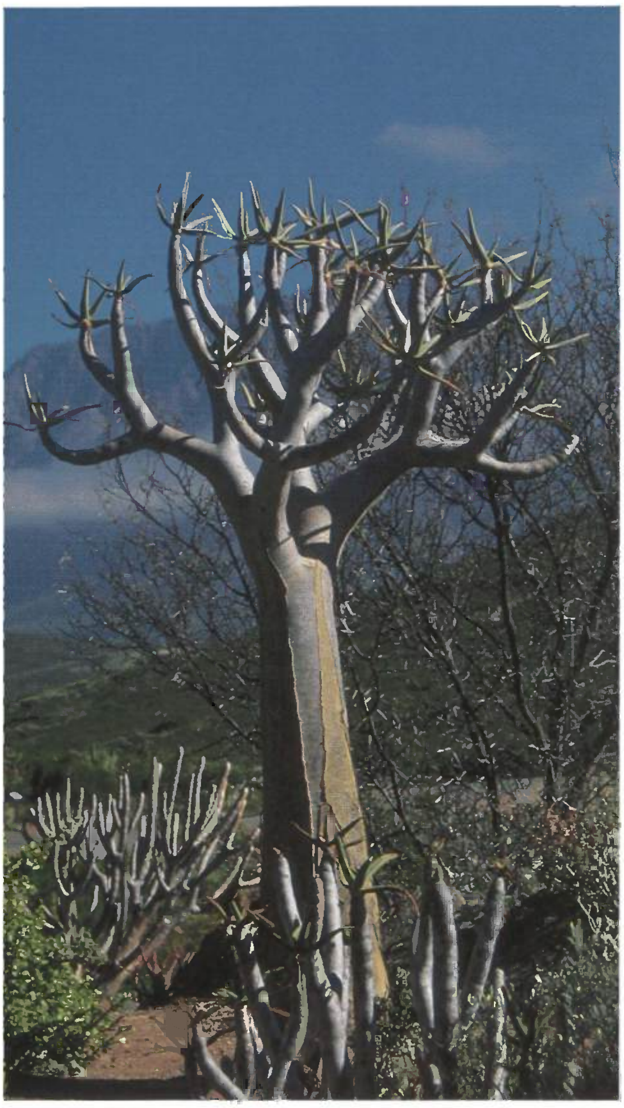

Quiver Tree *Aloe dichotoma*

Desert Plants

A journal devoted to broadening knowledge of plants indigenous or adapted to arid and sub-arid regions and to encouraging the appreciation of these plants.

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Please check out the new Desert Plants website at http://cals.arizona.edu/desertplants. With the help of Bill Singleton, the website was launched in April 2003. The website contains information on subscribing, back issues, special issues and includes a number of indices (author, subject, taxonomic). Comments and suggestions are welcome!

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Karoo Desert National Botanical Garden

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The Breede River Valley is well known by many visitors to South Africa for its fine wines, fruit and beautiful mountains. Not so well known is the Karoo Desert National Botanical Garden located near Worcester, capital of the Breede River Valley. It is one of the only, truly indigenous South African succulent gardens, and is one of only a handful of outdoor succulent gardens in the world. The Karoo Desert Garden is surely the showpiece of the Breede River Valley. In August and September of each year it becomes a magnificent carpet of colourful flowers. It can also be described as the gateway to the floral delights of Namaqualand – a one-hour drive from Cape Town.

History

The Karoo National Botanical Garden was originally established in 1921 on twenty morgen (app. 40 acres) of land at Whitehill near Matjiesfontein. It was known as the Logan Memorial Garden. Mr. J. Archer, former stationmaster at Matjiesfontein and lover of succulents, was the first curator appointed on 1st January, 1925. Unfortunately, owing to the lack of water and the re-routing of the national road, the garden was closed in 1935. Professor Compton, then Director of the National Botanic Gardens, decided to look for a more suitable location in late 1944.

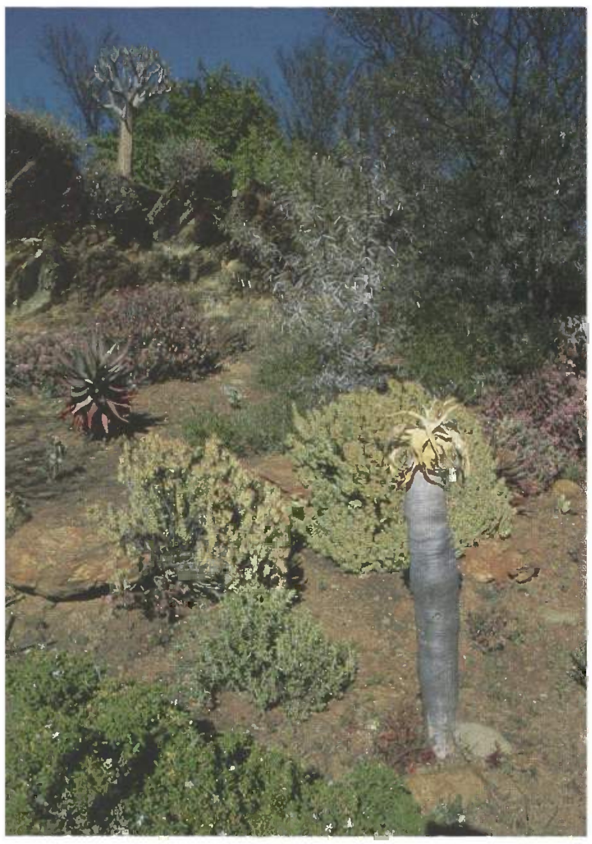
Two sites were considered for the Garden relocation. One was near Robertson and the other was just outside Worcester. The site chosen was thirty-six morgen (app. 72 acres) of land just north of Worcester, the current location of the Garden. The first curator, Mr. J. Thudicum, was appointed in August 1945. He was responsible for laying out the roads and pathways and for the planting out of many railway truck loads of plants from the old garden at Whitehill. Many of these plants, especially the *Aloe dichotoma* (quiver tree), still survive in the original area on a hillock to the right of the main entrance. It is interesting to note that Mr. Thudicum watered all the plants with buckets suspended from a wooden shoulder harness or balanced on the handlebars of his trusty bicycle. Mr. Thudicum is remembered in the botanical world for a showy yellow Mesembryanthemum, *Drosanthemum thudichumii,* which grows in shale hills just north of the existing garden.

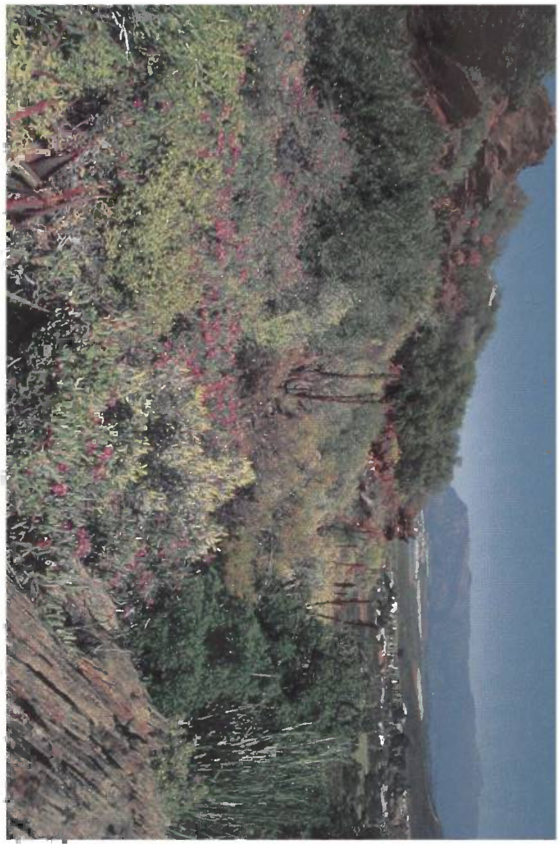
The Gardens' first horticulturist, Mr. R. C. Littlewood, was appointed in 1957 and served with great dedication until his untimely death in 1968. *Drosanthemum littlewoodii* is named in his honour. Mr Frank Stayner curated the Karoo Garden from 1959 until his retirement in July 1973. During this time, many buildings and plant houses were built and the irrigation systems (some still in use today) were installed. To him went the honour of naming *Stayneria,* a monotypic succulent genus in the Aizoceae (Mesembryanthemum Family).

In 2001, some 80 years after the garden started, the name was officially changed to Karoo Desert National Botanical Garden. This new name is consistent with other desert gardens throughout the world and international visitors can relate to this new name with relative ease. The addition of the word desert emphasizes that this is a garden that cultivates and displays plants from an arid environment.

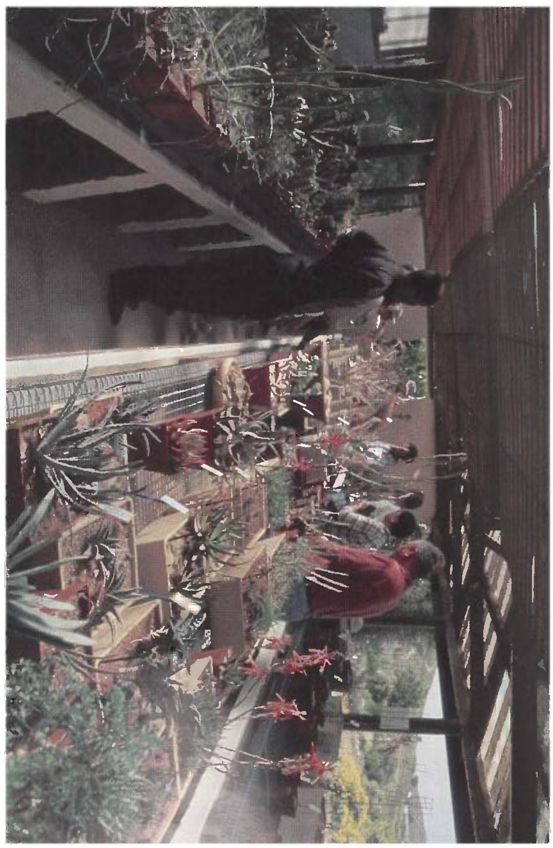
Living plant collections

Bruce Bayer, previously a technical assistant at this Garden, was appointed Curator in 1973 and really put the Karoo Desert Garden on the international succulent map. The scientific collections were increased and local and international succulent taxonomists made use of the living specimens in the plant houses. Mr. Bayer is internationally known for his work on Haworthias, having written 4 books and numerous scientific publications on the subject.The floral displays in the garden were extended, making the garden famous for its masses of colour in spring. The Karroid phytogeographic beds in front of the main administrative offices, displaying various regions of the Karoo, have proved

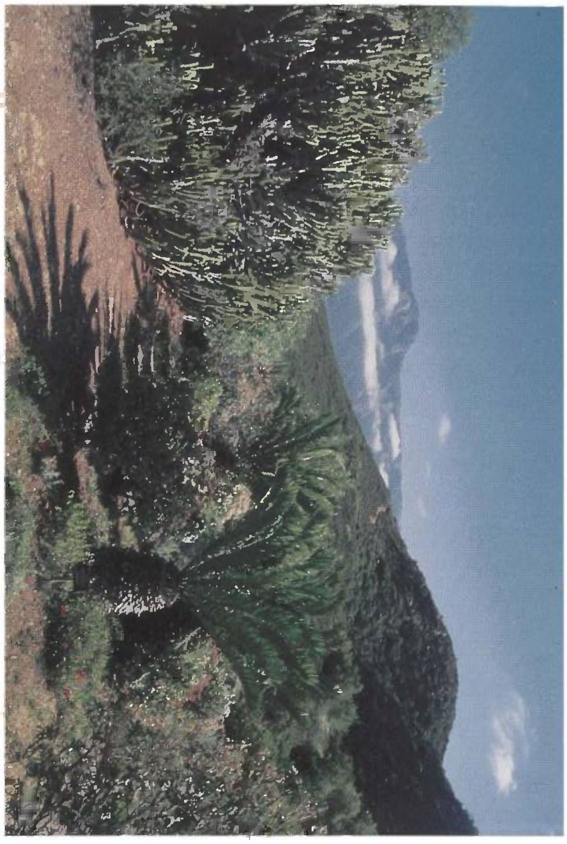




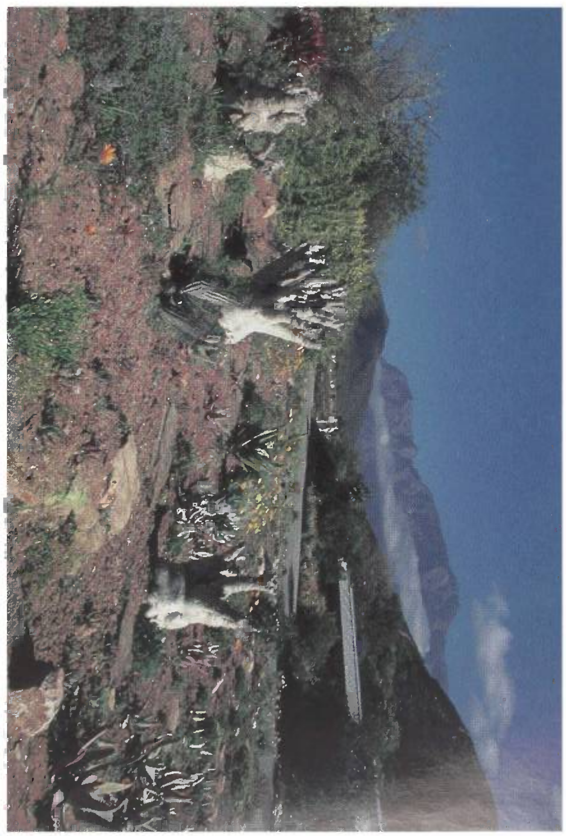
View from hillside in botanical garden to nearby town. (S. Carter)



Plants are initially grown in pots in a greenhouse. Author is on the right at the far end. (S. Carter)



Path in botanical garden. (S. Carter)



Several *Ciphostema jutae* in garden. (S. Carter) to be immensely popular with visitors. Some plants named in honour of Bayer's work include *Tylecodon bayeri, Haworthia bayerii, Gasteria brachyphylla var. bayeri* and *Anacampseros bayeriana.*

The Garden's main living plant collections are made up of the following families: Apocynaceae, Asclepiadaceae (now known as Apocynaceae), Aizoaceae, Amaryllidaceae, Asphodelaceae, Hyacinthaceae, Oxalidaceae, and Portulacaceae. In total, we have 94 genera that are being worked on. There are approximately 2000 species in the index collections (special growth houses). In total there are nearly 3700 species. This includes species in the index nursery, production nursery, garden and estate. In terms of succulent genera, for which this Garden is internationally known, the following collections are included: *Conophytum, Huernia, Avonia, Anacampseros, Gasteria, Haworthia, Gibbaeum, Lithops, Stapelia* and *Tylecodon.* The Garden also has extensive geophyte (bulb) collections including: *Brunsvigia, Haemanthus, Lachenalia. Ixia, Sparaxis, Strumaria, Boophane and Crossyne,* just to mention a few. Cape bulbs are world renowned for their exceptional beauty.

The succulent living collections are cultivated and displayed in four glass houses under a total of 330m². As fast as a house is completed it is filled to capacity! The bulb living collections are grown in raised beds. Each plant has its own compartment, allowing the plants to fully develop. Some of the more shade loving plants have a wooden, slatted roof (lath roof) over the individual specimens, giving much needed shade during the very hot summer. The concept of raised beds (1.5 m in height) works very well. Plants are grown under cooler conditions as a result of the deeper soils thus they are able to develop fully as opposed to the cramped growth restrictions of a plastic pot.

The original karroid phytogeographic collections are still on view near the main office. There are 1160 m² of karroid (semi desert) habitats growing in small beds each representing its own unique phytogeographical area. To date 30 karroid phytogeographic areas have been identified. There are nearly 900 species of plants in this area. The rest of the garden is used for display and educational purposes.

The Garden through the Seasons

The Karoo Desert National Botanical Garden has expanded from its original 33 ha to 154 ha (app. 239 acres) in extent with a developed area of eleven hectares (app. 25 acres). The Garden lies within the winter rainfall area of South Africa, receiving 65% of its annual 250 mm precipitation in the winter months of May to September. Summers are hot, up to 46 degrees C, and winters are cool and wet with light frost in the lower reaches of the garden. Minimum temperatures of 1 degree C have been recorded. Constant wind is experienced, especially during the winter.

The best time to visit the Karoo Desert garden is in spring when the Namaqualand daisies (Dimorphothecas), Bokbaai vygies (Dorotheanthus), Gazanias, Ursinias, Felicias and Arctotis all look their best. Spring bulbs, including Freesias, Tritonias, Lachenalias, Ornithogalums, Sparaxis, Babianas and Bulbinellas are also in flower. The actual peak time of flowering depends very much on the rain – when it falls and how much falls – but generally August to early September are the best times to visit the Gardens. The perennial vygies (mesembs), Drosanthemums and Lampranthus are at their best in early October. By November most of the annuals and vygies (mesembs) are over.

Spring and early summer are ideal times to take advantage of the Gardens' numerous nature walks. There is a network of pathways in the natural areas that are approximately 8 km long. These pathways are connected to the Fairy Glen hiking trail. There are three trails with information/story/picture boards. These trails are: 1) The Braille trail – 400 m; 2) The Shale trail – 1000 m and 3) The Karoo Adventure trail (including the new Bushmanland section, 2 ha). December, January and February are the dry, hot months of the year, but lots of hardy karroid trees have been planted in the car park and on the upper lawns. In time, these will give shade to the weary visitor. During summer some of the red and pink *Crassula* species are in full flower. It is during these hot months, when the natural karoo veld takes on a pale green hue, that fires become our biggest threat. The karoo veld, when devastated by fire, can take up to 30 years to recover.

Autumn is the time when many of the (dormant) summer bulbs push out their massive round heads of flowers. *Brunsvigia, Boophane, Cyrthanthus, Haemanthus, Nerine and Amaryllis* flower from March until May. The carrion-smelling flowering plants in genus *Stapelia, Duvalia, Piaranthus, Hoodia* and *Huernia,* flower from early March until the end of May. These flowers are characterized by their smell of rotten meat, which is very noticeable on hot, balmy afternoons. Autumn is also the time when the *Lithops* (stone plants), *Conophytum* (resembling stone plants) *Pleiospilos* (liver plant), *Dinteranthus, Argyrodermas* and *Lapidaria* all flower. These chunky, succulent plants, all of which make ideal pot plants, look their best after the hot, dry, summer months. Their iridescent flowers are spectacularly shown off against the stone-like bodies of the parent plants..

During the winter months the days are short. The first snow of the season usually falls on the Brandwacht Mountains (2100 m above sea level) to the north of the Garden. Rain falls sporadically, often accompanied by strong, north westerly winds. The attractive displays of *Oxalis* (clover-like plants) make a visit to the garden rewarding. These cheerful plants flower in a wide array of colours including pink, yellow, white, mauve and purple. The dullness of winter is brightened by the warm colours of the many flowering aloes. *Aloe dichotoma* (Quiver tree) and *Aloe ramosissima* with their bright, yellow flowers and pale, flaky bark, stand out like beacons in the wintry landscape. Other noteworthy aloes include: *Aloe ferox* (bitter aloe/Cape aloe), *Aloe barberae*, (the giant tree aloe from the eastern Cape) and *Aloe plicatilis* (fan aloe). Some of the vygie species start flowering from early winter through to spring. The mat forming *Cephalophyllum* (Mesemb.) make especially vivid displays with their metallic red, magenta, yellow and pink flowers.

The natural vegetation

According to Dr. Tim Hoffmann in *Vegetation of South Africa, Lesotho and Swaziland,* edited by A B Low & A G Rebelo, the Karoo Desert Garden falls within the Little Succulent Karoo. This region occurs in the hot, dry valleys between the two parallel, east-west trending mountains of the Cape Fold Belt. Thus, the physical geography, locality, climate, geology and soil create the ideal conditions for a succulent-rich flora.

The natural vegetation is characterized by small karroid bushes, hardy geophytes and succulents. The shrubby plants are mainly of the family Asteraceae. These include perennial shrubs such as *Pteronia, Elytropappus,* (Rhino bush), *Galenia, Rhus, Eriocephalus* and *Euclea* (Gwarribos). Plants of a succulent mesemb nature include *Antimima mucronata, Conophytum ficiforme, Drosanthemum bicolor, Drosanthemum speciosum, Drosanthemum micans, Drosanthemum striatum, Drosanthemum thudichumii, Drosanthemum barkwickii, Ruschia carolii, Ruschia multiflora* and *Ruschia pygmaea.* Other notable succulents are *Aloe microstigma, Cotyledon orbiculata, Crassulas* (25 species), *Euphorbia burmannii, Euphorbia mauritanica, Haworthia herbacea* var. *herbacea, Haworthia pumila, Orbea variegata, Othonna retrofracta, Senecio radicans, Quaqua mammilaris, and Tylecodon paniculatus.* Some of the succulent Pelargoniums are: *Pelargonium abrontanifolium, Pelargonium alternans, Pelargonium carnosum* and *Pelargonium karooicum.* There are 422 species found growing naturally on the estate. A large proportion of these species are succulents. There are also many geophytes (bulbs) of real beauty, such as the *Nerines, Massonias* and *Ornithogalums*, and the giant *Brunsvigia josephinae.*

The Garden Today

The Karoo Desert Garden, with a total developed area of 11 ha (approx. 25 acres), has a number of sections for displaying the horticultural potential of the various desert plants. These are mainly plants grown for their brilliant flower colour or sculptural forms i.e. caudiciform plants. Nearly 90% of the plants grown are of a water-wise nature. Other sections of the Garden represent the different karroid phytogeographical areas where desert plants are found. These include the Richtersveld, Little Karoo, Great Karoo, Bushmanland, Eastern Karoo, etc. The garden staff are continually expanding these areas so as to give the general public a greater picture of the wonders of the different areas of the succulent world.

The Garden has fairly comprehensive succulent and arid geophyte collections. A few of these include: *Haworthia, Conophytum, Lithops, Stapelia, Huernia, Avonia, Anacampseros* and *Tylecodon.* The arid geophytes include: *Brunsvigia, Hessea, Strumaria, Crossyne* and *Boophone.* Due to the tremendous floral diversity, it was decided to concentrate on selected families, genera and species.The main families which the Garden concentrates on are Amaryllidaceae (11 genera), Apocynaceae (2 genera), Aloeacea (3 genera), Aizoaceae (44 genera), Asclepiadaceae (new name Apocynaceae) (20 genera), Crassulaceae (1 genus) and Portulacaceae (4 genera).

In total, the Karoo Desert National Botanical Garden has about 3,700 taxa under cultivation. Nearly 65% of these are of a succulent nature. (We have recorded 375 species, of which, over sixty percent are succulents.) Rare and endangered plants are propagated and offered for sale in an attempt to take the pressure off of populations in the wild.

Future Development Plans

1.) Development of a 5000 m^2 (0.5 ha) *Aloe dichotoma* (Quiver tree) forest/Bushmanland area. This project is well under way with 300 young *Aloe dichotoma* plants having been planted. We plan to rescue another 200 young *Aloe dichotomas* in 2002 and 2003, bringing this project to its conclusion. Eventually there will be 500 quiver trees growing in this area, making it the largest planted quiver tree forest in the world.
2.) Development of a 1000 m^2 *Aloe barberae* (Bain's Aloe) forest. These plants were grown from cuttings and seed and planted during the winter of 2002.
3.) Further development and planting-up of Karroid phytogeographical areas.
4.) Development and planting-up of a *Pelargonium* hillock. This would feature mainly succulent Pelargoniums and Pelargoniums from the arid areas.
5.) Installation of automated irrigation systems for all lawned areas.
6.) Featuring the trees from the dry areas with emphasis on *Acacia*.
7.) Participation in a joint NBI/NBRI (Windhoek) project for the establishment of *Aloe pillansii* in South Africa and Namibia (in the Richtersveld). The mortality of these plants is extremely high, with a large percentage of mature trees dying. Recruitment of new seedlings has been sparse in places.
8.) Construction of an additional glass house for cultivation of *Aloe* species.

References

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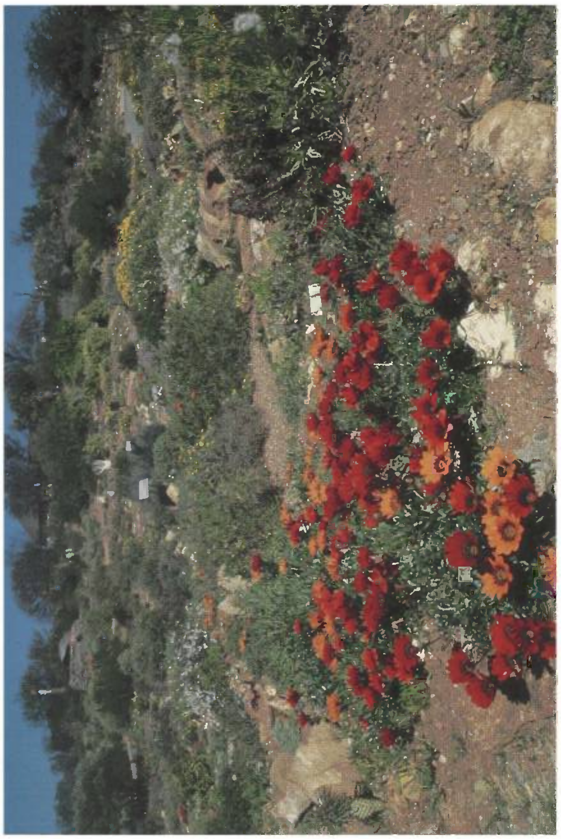
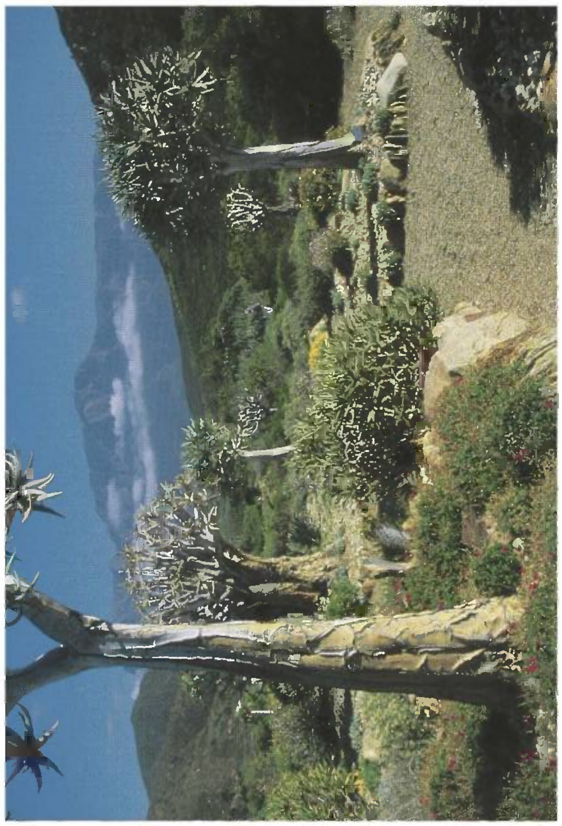
Incredible variety of growth forms. (S. Carter)


The colors of spring. (S. Carter)


Aloe pilansia (S. Carter)


Hillside at Karoo Botanical Gardens (S. Carter)

Botanizing in South Africa

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Introduction

A trip to the western Cape of South Africa in September 2002 opened my eyes to a whole new world of botany. The region was resplendent with annuals, perennials, bulbs, and succulents. Among the succulents there were a number of Aloe species. As with many other types of plants, some Aloes were just beginning to flower, others were in peak flower, while still others were finishing their flowering season. According to Goldblatt and Manning (2000), the Cape Floristic Region lies between latitude 31°and 34°30' S, and covers about 90,000 square kilometers of land area. With an estimated 9,000 species of vascular plants, the Cape Floristic Region is one of the most botanically rich and diverse areas in the world. By contrast, the state of Arizona covers roughly 295,000 square kilometers, yet only has about 3,400 species of vascular plants. In other words, Arizona has about 3 times the land area, yet slightly more than one third the plant species. While driving around the Cape Floristic Region, I marveled at several facets of the landscape and plant composition. First, in many areas the landscape resembled the basin and range topography found in many parts of southern Arizona and northern Mexico. Although the mountain ranges are only 1,000-2,000 meters in elevation, that is tall enough for winter freezing to affect vegetation. These mountain ranges are fractured with cliffs and valleys providing many habitats for species diversity. Second, there was a noticeable lack of tree species. The vast majority of plants were 1 meter high or lower. Third the wealth of bulbs and succulents was incredible. In fact, there were so many and our group spent so much time on our bellies that our drivers referred to us as "bottomists" (botanists with their faces down and rear ends up). Finally, there was a litany of family, genus, and species names to be learned, from the five families endemic to the Cape Floral Region (Penaeaceae, Stilbaceae, Grubbiaceae, Roridulaceae, and Geissolomataceae) to unfamiliar species in more familiar genera (*Salvia dentata*, *Gazania krebsiana*).

The Group and Itinerary

In February of 2002, I was offered a spot in what became known as the Lauren Springer Invitational. This was to be a trip to the western Cape Region of South Africa, and would include twelve plant fanatics from across the United States and England. Rod and Rachel Saunders, the proprietors of Silverhill Seeds in Capetown, would lead the group. We would also have two capable tour guides as drivers. This appeared to me as a once in a lifetime opportunity, so I scraped together enough money to venture out into unknown (to me) parts of the world. The first order of business is getting to Cape Town in order to start the trip. I figured the details were best left to the tour coordinator, so I had him make the flight arrangements. The first leg was from Tucson to Atlanta where I met up with 7 of the other tour participants. We then took the 15 hour South African Airways flight from Atlanta to Cape Town. The 15-hour flight combined with the 9-hour time difference made for a very long day. However, the excitement of being in a totally new part of the world gave everybody enough energy to visit Kirstenbosch Botanical Garden. We whet our appetite for new plants with an afternoon stroll through the gardens, snapping off pictures of Aloes, Cycads, Euphorbias, and Table Mountain. We left Cape Town and headed north toward our first night's destination of Clanwilliam. There were to be several stops along the way. We eventually got on to the N7 Highway

Although Aloes are succulent plants and we were in an arid area, we only saw ten different species. This is only 8 percent of the roughly 125 species found within the borders of South Africa. Other species occur in the western part of the Cape Floral Region, but they either were not near our route, or were missed because they were not in flower in September. Many of the South African Aloe species are found in the eastern and northern parts of the country. Aloe taxonomy is not immune to the debate that continues to plague the botanical world, however, the species we saw seem well defined.

Aloe comptonii
Compton's Aloe

Aloe comptonii is a low growing plant that is usually stemless, but with age may develop a creeping stem to 1 meter long. The leaves are blue-green, with a long triangular shape, and measure about 30 cm long. Leaf margins have few, short, white to light brown teeth. The leaf sap is deep yellow to orange. The inflorescence has three to eight branches, each terminated by a dense, capitate cluster of bright scarlet-red flowers at the tip.

Aloe dichotoma
Kokerboom, Quiver Tree

A distinctive species, *Aloe dichotoma* develops into a tree with a single trunk or occasionally 2-3 trunks. Many smooth branches form a dense, hemispherical crown. A mature specimen can eventually reach 4½ meters tall with a crown 3 meters across. Bark on the trunk splits and develops sheets with sharp edges. Long, narrow, succulent, blue-green leaves are about 30 cm long by 5 cm wide. In young plants, leaves are typically stacked in vertical rows, but with age the leaves become spirally arranged. Bright yellow flowers usually appear in winter, although there were a few plants with some flower spikes still blooming in spring.

We saw two very extensive populations with many old plants as well as plenty of young ones to keep those populations healthy. Our first photo stop was on the road from Kamieskroon toward the town of Gamoep. Our second stop was southwest of the first. We were traveling from Nieuwoudtville to Loeriesfontein when we stopped for a second, very extensive forest of *Aloe dichotoma*. The species name *dichotoma* refers to the dichotomous branching habit. The common name Quiver Tree comes from the use of hollow stems as quivers.

Aloe ferox
Fierce Aloe
Aloe ferox is a single stemmed plant that reaches two meters or more tall. Thick, succulent leaves are broad at the base, gradually and evenly tapering to the tip. Leaves measure about 10 cm wide at the base and 40-50 cm long. They are a dull green to gray green with dark reddish brown spines along the edges and frequently both surfaces, especially the underside. Dry leaves remain on the trunk. The inflorescence consists of 5-12 upright branches with numerous red, reddish orange, or sometimes yellow flowers. In the warmer parts of its range, flowering generally occurs in winter and early spring. In the colder parts, flowering is delayed until summer and fall.

Aloe ferox has a wide distribution, ranging from Western Cape Province through Eastern Cape Province, and into Lesotho and the Free State. We saw extensive populations in the Groot Swartberg, one of a series of east-west mountain ranges dividing the Little Karoo to the south from the Great Karoo to the north. The species name ferox is derived from the Latin *fero* meaning fierce or wild. This is in reference to the fierce spines found on the leaves.

Aloe glauca
Blue Aloe, Blouaalwyn
Plants of *Aloe glauca* are usually stemless or occasionally with short stems. Blue gray leaves are up to 40 cm long, with reddish brown teeth along the margins. Upper leaf surfaces are smooth while the lower surfaces frequently have small spines near the tip. The inflorescence is an unbranched raceme. Large leafy bracts cover the peduncle and flower buds. The buds are erect while open flowers are pendulous. Flower color is variable, ranging from pink to pale orange. Flowers appear in late winter and early spring.

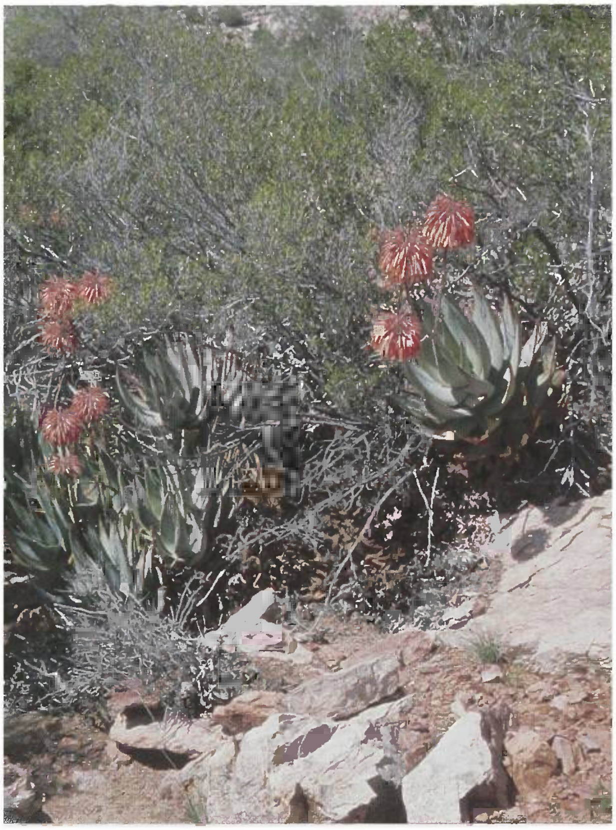
Aloe glauca is found on rocky hills and mountain slopes in the dry parts of the southwestern Cape. It can be found in Namaqualand in the northwestern part of the Cape Region and the Laingsberg (Long Mountains), one of a series of east-west mountain ranges that separate the Little Karoo from the Great Karoo. We saw just one plant in the landscape outside the Kamieskroon Hotel. Apparently *Aloe glauca* does not grow well in cultivation in areas with summer rainfall. The Afrikaans common name of Blouaalwyn translates to Blue Aloe in English, and the species name *glauca* refers to the blue gray leaf color.

Aloe khamiesensis
Khamies Aloe, Tweederly, Aloeboom
An erect and usually single stemmed plant, this Aloe will reach three meters tall. Leaves are long lanceolate, about 8 cm wide at the base, and taper to the tip. Reddish brown, triangular teeth adorn the margins while small white spots appear on both surfaces. The inflorescence branches into 4-8 racemes, each measuring about 30 cm long and crowded with orange-red flowers with greenish yellow tips. Flowers usually appear in early winter.

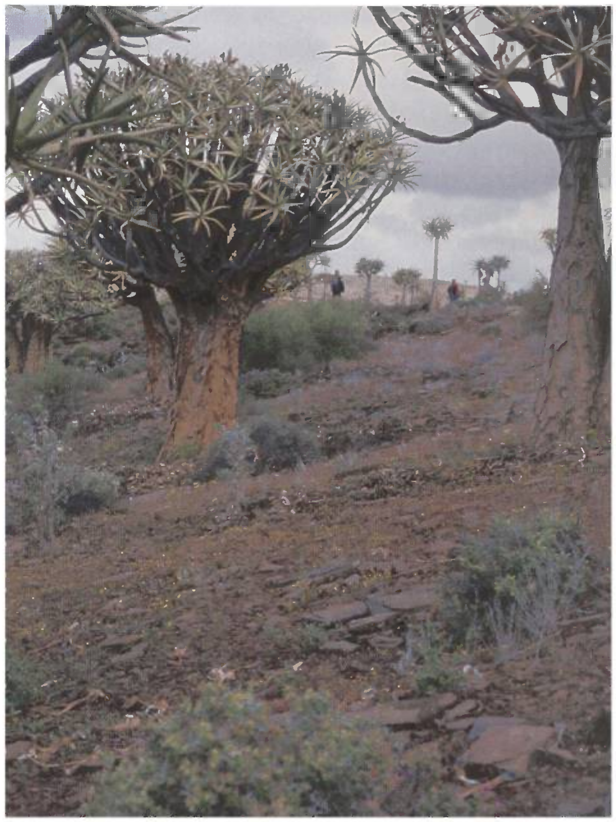
From the road we spotted mature, single trunked plants on rocky hillsides in and around the town of Kamieskroon and the Khamiesberg mountains. The species name *khamiesensis* is derived from its occurrence in the Khamiesberg where the type collection came from. It was an overcast, drizzly day when we drove out from Kamieskroon to Leliefontein, and we were unable to get decent photos of these plants. Apparently *Aloe khamiesensis* is somewhat difficult to cultivate, and South African horticulturists recommend enjoying them in their natural habitat. Recorded common names include Tweederly, Aloeboom, and Wilde-aalwyn.

Aloe lineata* var.*muirii
Aloe lineata develops a trunk to about 2 meters tall, which is covered with the old, dried leaves. Rosettes are compact with bluish green leaves having distinct reddish longitudinal lines on both surfaces, and firm reddish brown teeth along the margins. One to four, simple racemes develop consecutively on a single rosette. Large, leafy bracts cover the flower buds. Light pink to bright red flowers are spreading, then pendulous upon maturity. *Aloe lineata* flowers in summer and early fall, while variety *muirii* flowers in winter and spring. Plants are found in thick, brushy vegetation on flats and rocky slopes along the southern part of South Africa. The yellow-green leaves with distinct red striations, larger marginal teeth, and winter-spring flower time separate *Aloe lineata var. muirii*. The species name *lineata* refers to the leaves being marked with fine, parallel lines.

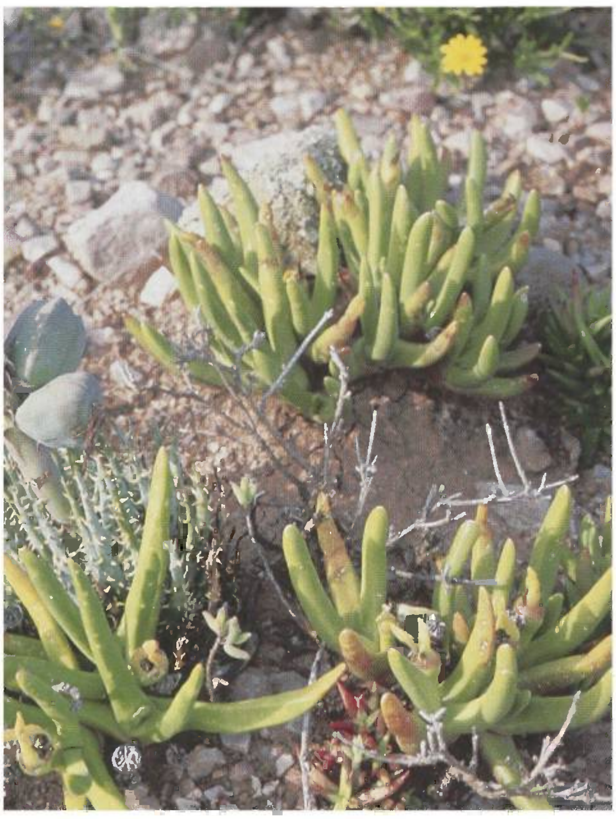
Aloe longistyla
This small, stemless plant is usually solitary, but occasionally has two to three rosettes, or rarely as many as ten. Small, gray-green leaves have a noticeable waxy layer, measure about 15 cm long by 3 cm wide at the base, and are covered with rigid, white spines on both surfaces. Simple racemes occur singly or in pairs, measure about 20 cm long, and have up to 50 flowers. Salmon pink to coral red flowers are relatively large, up to 5.5 cm long and 1.0 cm in diameter. The upper half curves up, and the exserted stamens and style protrude nearly 2 cm beyond the tube. Flowering time is generally in late winter. The fruit capsules are exceptionally large for such a small plant.



Aloe comptonii



Aloe dichotoma



Aloe longistyla

Aloe microstigma

This diminutive species occurs in the dry parts of the Little Karoo and Great Karoo. Plants never occur in dense groups, and are difficult to find as they are small and usually tucked in among shrubs. We saw few plants on one hillside outside the town of Calitzdorp in the Groot Swartberg, which lies in the south-central part of the Western Cape. This mountain range is part of several east-west ranges that separate the Great Karoo (north of the mountains) from the Little Karoo (south of the mountains). Plants of *Aloe longistyla* should be placed in soil with good drainage. Local common name is Ramenas and the species name *longistyla* is derived from the long exserted style.

Aloe melanacantha
Black Thorn Aloe
Plants are either single or occasionally occurring in groups of as many as ten or more rosettes. They have short stems that are usually hidden by the leaves. Thick, succulent leaves are long and narrow, measuring about 20 cm long by 4 cm wide at the base, gradually tapering to the tip. They curve slightly up and in, giving a dense, rounded form to the plant. The leaves are green to brownish green and covered with large, black thorns along the margin and keel. The inflorescence is a simple raceme with tubular, bright red flowers that turn yellow at maturity. Flowering occurs in early winter.

Plants are found in dry, sandy, or rocky areas at altitudes between 300 and 900 meters (1000-3000 feet). They grow on slopes and hills at the northern tip of the Western Cape and the western part of the Northern Cape. They can be found in the Bokkeveld Mountains around Nieuwoudtville (the Bulb Capital of the World), north to southern Namibia. Average annual rainfall is 125-250 mm (5-10 inches) and falls in the winter. Summer temperatures can reach over 38 degrees Celsius (100 degrees F), while winter lows seldom reach below freezing.

Aloe melanacantha is strictly a winter grower and should be treated as such. Grow in soil with good drainage, water regularly in the winter, and sparingly in summer. Do not keep the soil soggy any time of the year. The species name *melanacantha* translates to black thorn, and refers to the black thorns along the leaf margins and keel.

Aloe microstigma
Tiny Spot Aloe
Usually found as single rosettes or occasionally forming small groups. They have short stems, sometimes approaching 50 cm tall. Long-triangular leaves measure up to 30 cm long by 6 cm wide at the base, tapering evenly to the tip. They are blue-green to reddish green and covered with numerous, very small white spots from which the species name is derived. Leaves have sharp, reddish brown teeth only along the margins. The simple raceme can reach about 1 meter tall with 2 or 3 racemes occurring on each plant. Tubular flowers are red when in bud and open yellow. Flowering time is in winter.

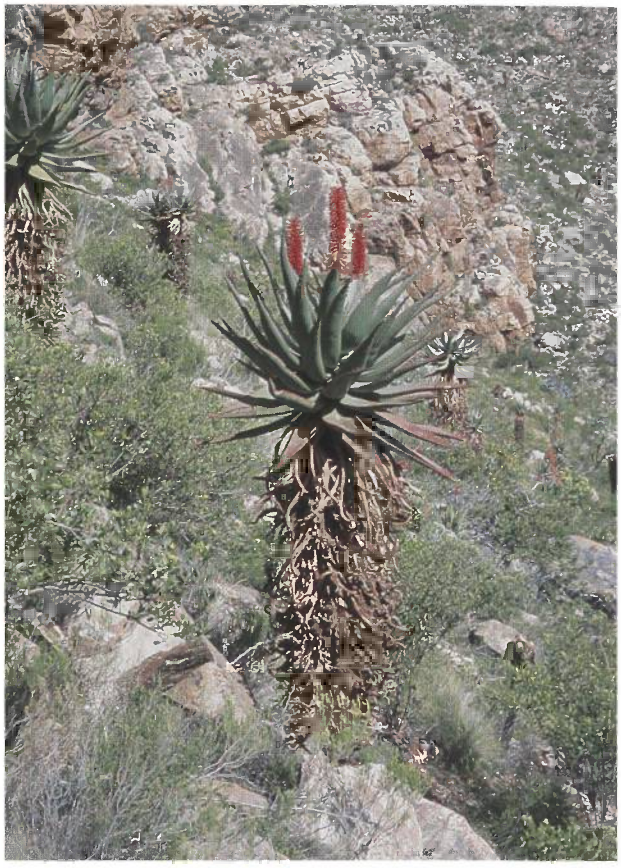
Aloe microstigma has an east-west distribution in the dry interior of the Western and Eastern Cape Provinces. We encountered plants at about 650 meters elevation south of the town of Laingsburg in the Witberge Mountains of the Western Cape. They were growing on dry slopes with a variety of succulents and shrubs. The species name, *microstigma*, refers to the small spots that dot the leaves. There are no African common names for *Aloe microstigma* however; in cultivation it has been called Tiny Spot Aloe.

Aloe mitriformis
Bishop's Cap Aloe, Miter Aloe, Gold Tooth Aloe
Aloe mitriformis has sprawling, ground-hugging stems that can reach two meters long with only the leaf-bearing tip being upright. Thick, succulent leaves are bluish green, with small white teeth along the margins. The inflorescence develops up to five branches. Each terminated by a compact, rounded cluster of bright red flowers. Flowering occurs in the summer.

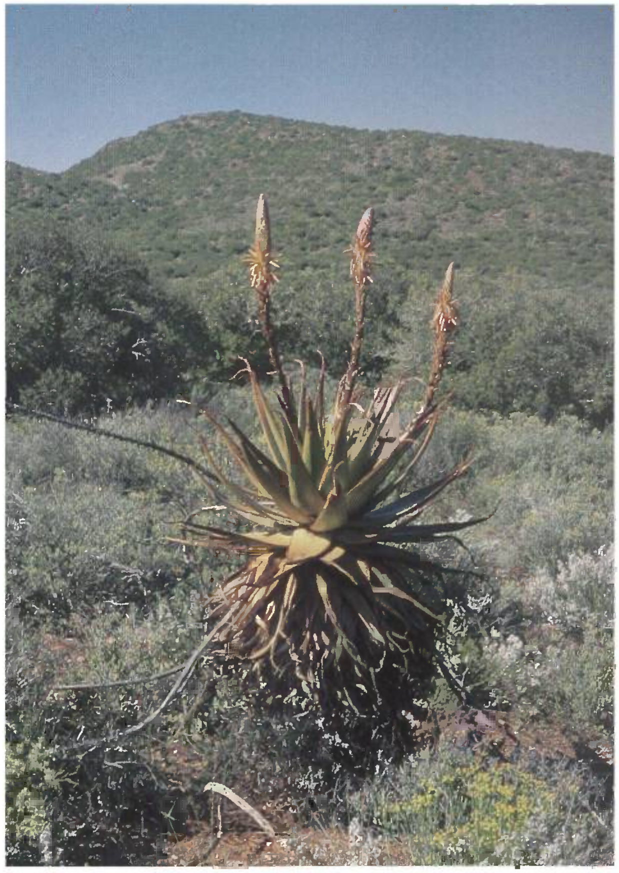
Distribution of *Aloe microformis* runs north-south in the Western Cape Province. Plants are found near Genadendal in the Riviersonderendberge Mountains (roughly 200 kilometers east of Cape Town) north to the Bokkeveld Mountains near Nieuwoudtville. We encountered *Aloe mitriformis* on the road to the Gifberg outside Vanrhynsdorp. *Aloe mitriformis* is named for the miter-like form of the rosettes. The common name of Bishop's Cap Aloe refers to the shape of the inflorescence, and Gold Tooth Aloe comes from the yellow-gold color of the teeth on the leaves. Locally in South Africa, the plant is called Kransaalwyn.

Aloe striata
Coral Aloe
Coral Aloe plants are generally stemless, although very old plants can develop creeping stems about 1 meter long that are covered by the old, dry leaves. Rosettes grow to 40-50 cm tall by 60-70 cm wide. Blue-green leaves are wide and flat with distinct vertical lines, and reddish margins without any spines. Mature leaves measure up to 45 cm long by 10-12 cm wide. The inflorescence forms a multiple branched, corymbose panicle. There are 1-3 inflorescences per plant during the flowering season. Flowers are pinkish red to bright orange, while a yellow form has been reported from the Eastern Cape Province.

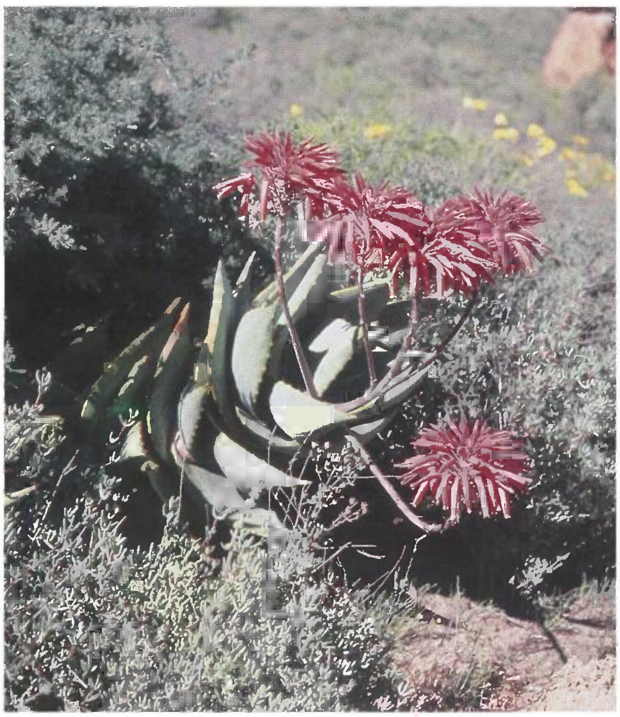
Currently, *Aloe striata* is considered to have three distinct subspecies. *Aloe striata* ssp. *striata* has pale blue-green leaves with distinctive reddish or pinkish margins. It has a very dense and compact inflorescence that appears in late winter and spring. The subspecies *striata* occurs on rocky slopes and hillsides in the dry parts of the Western and Eastern Cape Provinces. Rainfall averages 375-500 mm and occurs either periodically throughout the year or only in



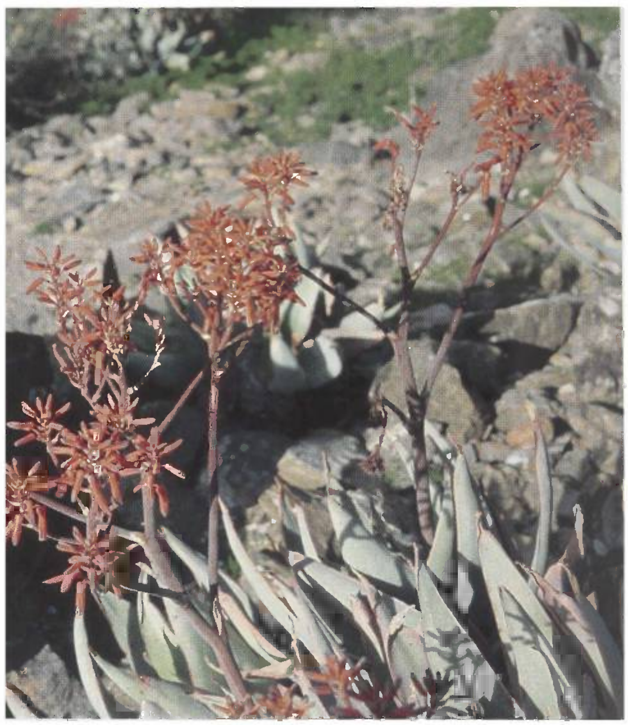
Aloe ferox



Aloe lineata



Aloe mitriformis



Aloe striata

summer in some areas. The summer temperatures reach over 38 degrees C (100 degrees F) and in the northern parts of its range, winter temperatures can fall below freezing.
Leaves of *Aloe striata* ssp. *karasbergensis* are more brownish with distinct longitudinal lines and conspicuous white margins. The inflorescence is more open and appears in summer. Plants are found on rocky outcrops and flats in red, sandy soil in the central and northwestern part of the Northern Cape Province. Summer temperatures can reach over 38 degrees C (100 degrees F) and winters are cold. Rainfall is in winter and averages 125-250 mm per year.

Aloe striata ssp. *komaggasensis* has faint lines and white edges on the leaves. Flowering for subspecies *komaggasensis* is in the summer. The distribution is restricted with plants occurring only in the mountains around Komaggas in Namaqualand of the far western part of the Northern Cape Province. The species name *striata* is derived from the longitudinal lines (striations) on the leaves. The common name of Coral Aloe refers to the coral orange flower color that is most prevalent for this species. Some South African common names are Blouaalwyn, Gladdeblaaraalwyn, and Streepaalwyn.

Aloe striata is an attractive ornamental found periodically in the nursery trade. A hybrid of *Aloe striata* and *Aloe saponaria* is found in the nursery trade also. This plant tends to be hardier to the frost, and offsets readily, ultimately forming large clusters to 2 meters across. The faint spots and indistinct teeth on the leaves readily distinguish the hybrid from the pure species.

Aloe variegata
Partridge Breast Aloe
A stemless plant reaching about 25 cm tall and offsetting to form clumps about 30-45 cm across. The deep green, thick, succulent leaves are deeply folded have many white spots on both surfaces. Minute teeth are regularly spaced along the white edged margin. The inflorescence is either simple or with as many as 3 branches, with as many as 6 inflorescences occurring in one rosette. Flowers are dull red to pinkish and appear in late winter.

Aloe variegata is found growing tucked in among small shrubs in dry regions of the Karoo, Namaqualand, and southern Namibia. Rainfall occurs in either winter or summer depending on the area, and ranges from 125-500 mm annually. Typically summers are hot, reaching 38 degrees C or more, and winters can experience hard frost. Because plants grow tucked among shrubs, they were not easily spotted unless in flower. We saw several populations, none with an abundance of plants. Some of our stops for *Aloe variegata* were on the R354 from Middlepos to Sutherland.

The species name *variegata* refers to the variegated leaf appearance. Some South African common names include Kanniedood, Bontaalwyn, and Luckhoffaalwyn. It is commonly called Partridge Breast Aloe in the nursery trade. *Aloe variegata* is easily cultivated, and can be propagated by seed or offsets. Place in filtered light and a soil with good drainage.

Conclusion

Although our trip was not geared specifically for succulent plants, we saw a wide variety of *Aloe* species in several habitat types. We traveled from the winter wet, summer dry Namaqualand where *Aloe dichotoma*, *A. glauca*, *A. khameisensis*, *A. melanacantha*, and *A. mitriformis* grow; across the dry flat terrain of the Little Karoo come *Aloe humilis*, *A. lineata*, *A. longistyla*, *A. microstigma*, *A. striata*, and *A. variegata*; and through the rocky, canyon habitat of the Groot Swartberge where *Aloe comptonii*, and *A. ferox* prevail. With such diverse habitat in a relatively small area, a traveler to South Africa whose primarily interested in plants is bound to have his or her interest piqued by the incredible array of plants regardless of the time of year. If your interest is spring wildflowers, visit the Western Cape Province anytime in September. (All photographs by G. Starr)

Aloe variegata

The Color Encyclopedia of Cape Bulbs

reviewed by Greg Starr

By John Manning, Peter Goldblatt, and Dee Snijman, 2002,
Timber Press
The Haseltine Building, 133 S.W. Second Ave, Suite 450
Portland, OR 97204 USA
ISBN 0-88192-547-0, hardbound, 486 pp., 611 color photos, 2 color maps, 2 tables, 8½" x 11", $59.95.

After a visit to the Cape Region in September 2002, I was smitten by the geophytes. When given the opportunity to review this book, I jumped at the chance and was not disappointed.

The Color Encyclopedia of Cape Bulbs is more than the title alludes to. It is a comprehensive look at the geophytes ("plants that have their renewal buds buried underground") of the Cape Floristic Region of South Africa. There are some exclusions such as the whole family Anthericaceae, and the genera *Bulbine* and *Trachyandra* which are not covered. In spite of these omissions, this is an exceptional book, and nearly 1200 species of Cape geophytes are treated with over half the species represented by photographs, all taken in the wild.

The Cape Floral Region is extremely rich vegetatively. For example, California is more than three times the size of the Cape Floral Region, yet has about 5,000 species of plants, compared to about 9,000 species in the Cape Floral Region. The area is particularly rich in geophytes. Of the 9,000 species, about 1,500 (17%) are geophytes.

The book opens with general information about the Cape Region, moves through the history of Cape Flora exploration, and includes sections covering the climate, geology and soils, and the biogeography. The section on biogeography covers seven phytogeographic centers, six of which are within the Cape Floral Region. The seventh, the Roggeveld Center lies just outside the Cape Floral Region, but the geophytic plants are so closely allied that the authors included this region. The other six regions include the Northwest Center, Southwest Center, Agulhas Plain, Karoo Mountain Center, Langeberg Center, and the Southeast Center. The next chapter is called Bulbs in the Garden, and covers bulb structure and cultivation. The cultivation section provides information on temperature and light, soil, planting, watering, fertilizing, pests, and seeds.

The heart of the book is the encyclopedic section, which is arranged alphabetically by genus rather than by family then genus. I find this to be the best arrangement as there had been so much recent work on the families that it is easiest to work with genus and species. Each species ID accompanied by a detailed description, flowering period, and distribution information.

I especially like the inclusion of the two sets of dichotomous keys, one to genus, and one to species within each genus. This is particularly helpful when trying to determine an unknown geophyte.

The book closes with a list of bulb and seed suppliers, an extensive glossary of terms, a comprehensive bibliography, and a complete index of synonyms.

The Color Encyclopedia of Cape Bulbs will be a useful tool for gardeners, botanists, and bulb enthusiasts in general. This book should be within arms reach for anyone interested in geophytes from the Cape Floral Region.

Arizona Gardener's Guide

reviewed by Margaret Norem

By Mary Irish. 2003,
Cool Springs Press
P.O. Box 141000
Nashville, Tennessee 37214
ISBN 16888608, softcover, 271 pages, 221 color photographs, 1 table and 1 cold hardiness zone map for Arizona. $24.99

Everything you have seen in the local nursery and considered planting in your Arizona landscape is discussed in this book. Emphasis is on everything. Grasses, roses, palms, agaves, tulips, and more are detailed. The format for each plant includes when and where to plant, growing tips, companion planting, and a did you know section. A very good quality color photograph accompanies each plant discussion. A detailed cold hardiness zone map of Arizona helps the gardener identify the best plants for his area. The book is divided into eleven plant sections (annuals, bulbs, roses, etc) and alphabetized according to common name within each section. Each section is also color coded along the top of the page. A very well organized, well written and enjoyable book, it is fast becoming the Arizona Master Gardener's bible.

Hunting the Elusive Organ Pipe Cactus on San Esteban Island in the Gulf of California

Thomas Bowen
The Southwest Center
The University of Arizona
Tucson, Arizona 85718

Admissions and Excuses

Routine field projects sometimes have strange outcomes.This is a tale of how an offhand botanical observation, made during the course of an archaeological survey, took on a life of its own and led in a totally unanticipated direction. It is also a story whose ending has yet to be written, because completing it will need biological expertise beyond a simple ability to count organ pipe cacti. By telling the tale as it has unfolded so far, perhaps an inquisitive botanist can be enticed to bring this story to a satisfactory conclusion.

Innocent Beginnings

On January 4, 1982, Dan Bench, Dana Desonie, and I wandered into a small secluded drainage in the northwest corner of San Esteban Island, a rugged chunk of land in the middle of the Gulf of California. Looking around, we were startled to find ourselves in the midst of a thin stand of organ pipe cactus (*Stenocereus thurberi*). Although we were doing archaeology, not botany, finding these cacti was a matter of some interest. In the first place, organ pipe cacti ("orpis", to use Richard Felger's whimsical nickname) produce a fruit that was an important food resource for native peoples on both sides of the Gulf – Seri Indians (Comcáac) on the Sonoran side and the historic Cochimís in Baja California. In the second place, the only published reference to these cacti on San Esteban that we knew of had characterized them as "rare" (Felger and Moser 1974: 267).

Until that day, our own observations seemed to confirm that organ pipes were few and far between. Because of their cultural importance, we had been keeping a lookout for them, but in our 44 days of field work over two years we had seen just seven plants, one of which was dying. So it was a quite a surprise to count about 40 organ pipes mixed among the ubiquitous cardóns (*Pachycereus pringlei*) and pitahaya agrias (*Stenocereus gummosus*) in that one small valley. Although we put in many more weeks of archaeological fieldwork throughout the island during the next five years, we never saw another organ pipe. Except for Orpi Valley, as we came to refer to it (Figure 1), organ pipes on San Esteban Island seemed rare indeed.

It is not surprising that the Orpi Valley stand was unknown to the botanical community, for it lies in a remote corner of a remote island. San Esteban Island, about 40.7 km^2 in area, is situated in the upper Gulf of California at approximately 28°42' north latitude and 112°35' west longitude (Figure 2). Though only 11.6 km from Tiburón Island, it is about 55 km from the nearest port on the Sonoran mainland (Bahía Kino) and about 38 km from Punta San Francisquito, the closest port on Baja California. Because of its isolation, San Esteban has a long history of being bypassed by just about everyone. The first scientists to set foot on the island arrived in 1911 and stayed less than 24 hours, setting the pattern for most scientific visits during the next 50 years (Bowen 2000: 289-313). Since almost every expedition disembarked on the eastern shore at one of the few feasible landing places, it is little wonder nobody found Orpi Valley, tucked away in the opposite corner of the island a slow 8 km trudge away (see Figure 3). In fact, botanists didn't know there were any organ pipes on the island until Richard Felger discovered some in 1965 (Felger 1966: 418; 2003: pers. comm.).

The peculiar concentration of organ pipes in Orpi Valley called for an explanation, so I mentioned the stand to Felger. Felger had probably spent more time on the island than any other botanist and was rightly skeptical until I showed him a slide of the valley with organ pipes plainly visible. He immediately pointed out that that corner of the island is sometimes wrapped in sea fog and would catch the brunt of northwesterly storms. Very likely, he speculated, the extra moisture enabled organ pipes to thrive in this one locality while the rest of the island was too arid to sustain more than a few hardy individuals (Richard Felger 1983: pers. comm.). This "Microclimatic Hypothesis", as I shall refer to it, seemed entirely reasonable, and for the next 15 years I thought little more about it.

Then in 1998 an entirely different explanation began to emerge, due in part to conversations with Gary Nabhan. At that time, Nabhan had begun working with the Seris on ethnobiological questions and was conducting his own field work on San Esteban Island. Building on earlier suggestions (e.g. Yetman and Búrquez 1996), he was pondering the potential role of native peoples, especially Seris or their ancestors, in dispersing native plants and animals in the Gulf region, including the Midriff islands. Intrigued by that idea, I told him about the Orpi Valley organ pipes and wondered aloud if they might in some way be the result of human activity, for Orpi Valley is not far from a locality that was heavily utilized by the island's former Seri inhabitants. Nabhan in turn wondered if the stand could be related to the traditional Seri birth practice of burying the newborn's placenta, a practice he was currently investigating (Gary Nabhan 1998: pers. comm.).

The Seri practice of burying the placenta was first described by Moser (1970: 205) and Felger and Moser (1985: 254). They reported that the placenta was buried next to a cardón

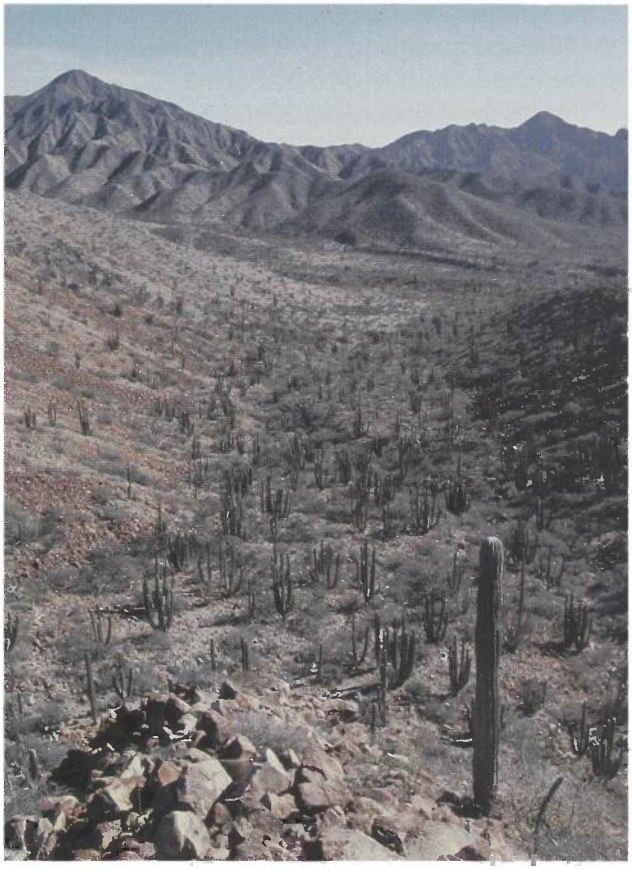


Figure 1. View down Orpi Valley looking southeast. Organ pipes occur in the valley floor and up both flanks. (January 1982)

or saguaro and that five small plants, of any species, were buried with it. Nabhan, however, describes the practice quite differently. He maintains that the plants accompanying the placenta were long-growing succulents, including cacti. He further maintains that they were not buried but were *transplanted* over the placenta as live individuals, and that they might be brought for this purpose from locations more than 50 km away (Nabhan 2000: 548-50; 2002: 409).

Nabhan suggests that placental burial, as he describes it, may help explain disjunct populations of cacti in Seri territory, and he cautiously raises the possibility that it might have introduced new species to some of the islands. He cites, as possible examples, the "out of typical habitat" stand of organ pipes in Orpi Valley and a second cluster of organ pipes which he observed "in the middle of San Esteban." The implication is that these two stands could be the result of Seri placental burials (Nabhan 2000: 548-50), thereby creating what I shall call the "Placental Burial Hypothesis."

Nabhan's speculations raised interesting questions that merge biogeographical issues with anthropological ones. But they were also predicated on the accuracy of the distribution of organ pipes as we had perceived it. Our own observations in the 1980s had been incidental to our archaeological mission, and nobody had ever conducted a serious census. Consequently, when Dan Bench, Larry Johnson, and I had an opportunity to visit the island in February 2001, we thought it might be useful to spend a couple of days looking specifically for organ pipes.

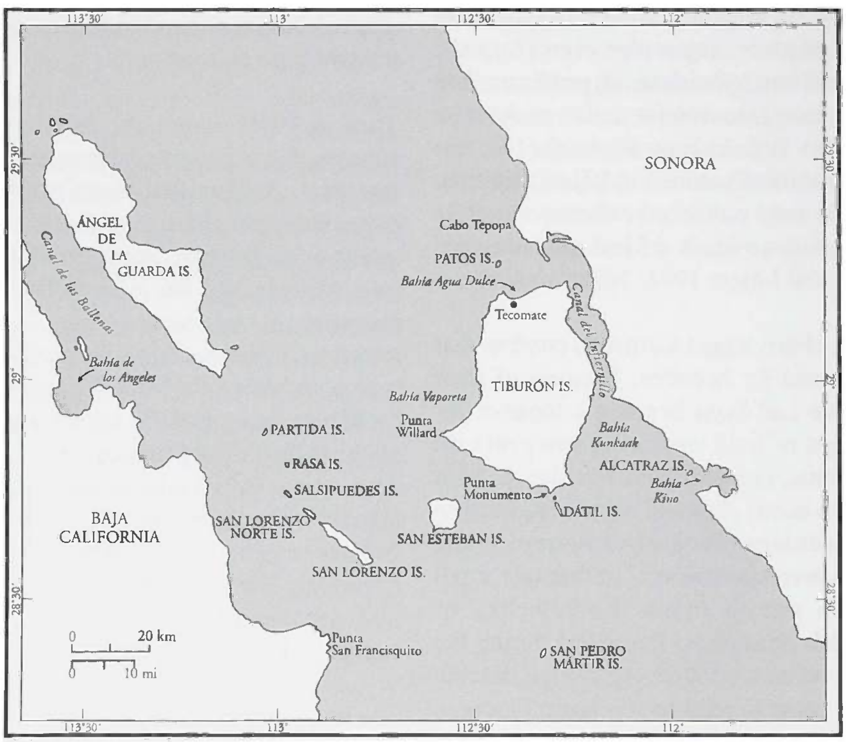


Figure 2. The Midriff region of the Gulf of California

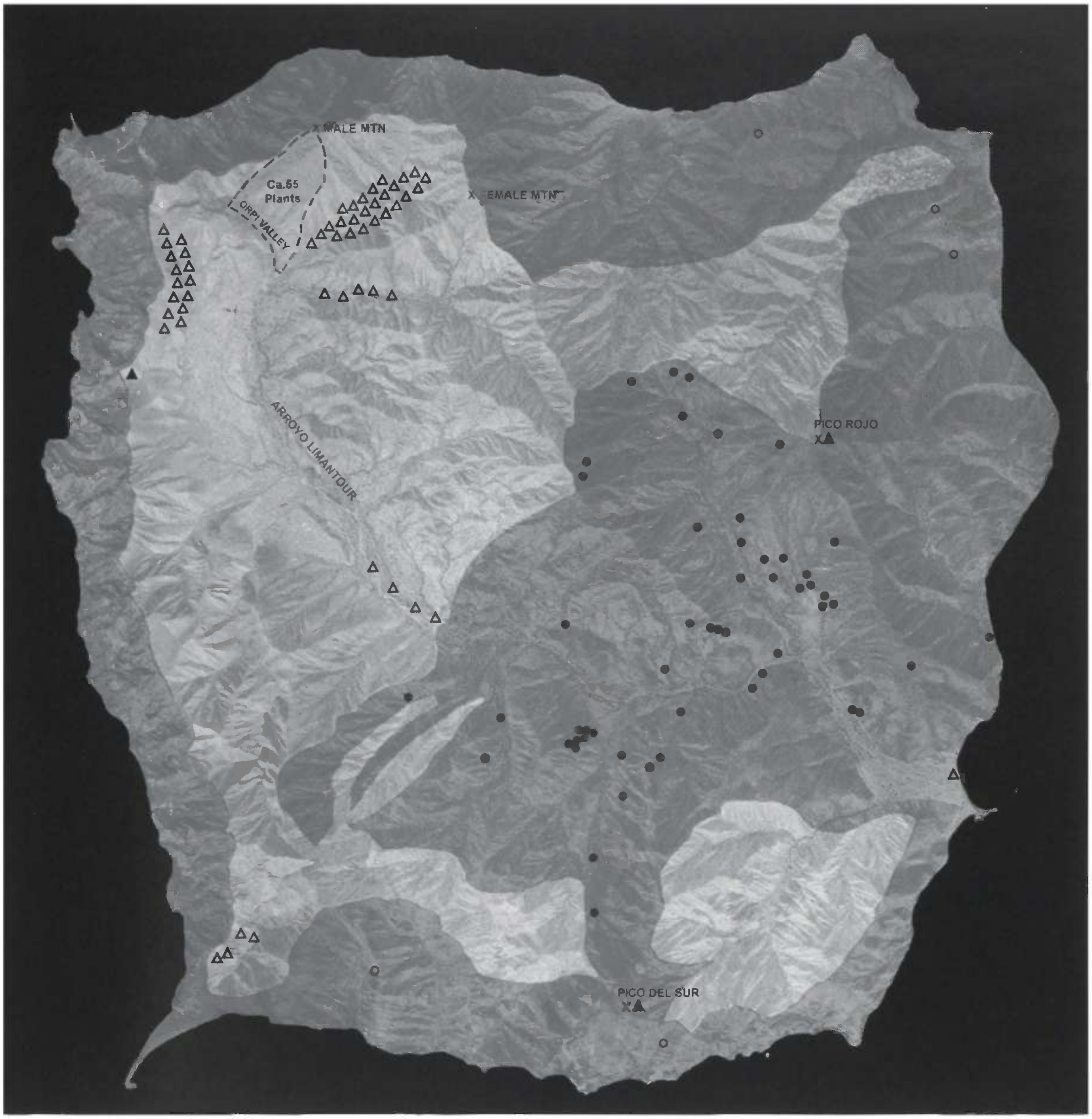


Figure 3. Aerial view of San Esteban Island showing the area surveyed in April 2002 (dark shading) and the location of the island's known organ pipes. Dots represent plants recorded in April 2002; triangles are plants encountered previously. Open dots and triangles indicate uncertain locations. Scale is approximately 21mm = 1 km or 1.33 inch = 1 mile. The image is an uncontrolled mosaic of four air photos digitally processed by Kevin C. Horstmann.

The First Orpi Hunt, February 2001

We set out with just two goals in mind. One was to make a more accurate count of the organ pipes in Orpi Valley. The other was to locate the stand Nabhan reported "in the middle" of the island. Our census of Orpi Valley generally confirmed our hasty 1982 count. From a good vantage point above the mouth of the drainage, we scanned the area with binoculars and independently counted organ pipes. Our counts ranged from 48 to 62 for a mean of 55 plants. In 1982 we had counted 40 plants in the drainage proper. This time we included the entire southwest face of Male Mountain, which probably accounts for the higher figure. We did not scan the southwest side of Orpi Valley, which we could not see well from our location, or the total would have been greater still. As to population characteristics, the Orpi Valley plants spanned the full range of ages, from very small (under 1 m) and presumably young individuals to large adults, and included a few skeletons.

Our only surprise was to discover that organ pipes are not as closely confined to Orpi Valley as we had thought. Orpi Valley is one of three drainages that converge at nearly the same point to form upper Arroyo Limantour (Figure 3). Orpi Valley itself drains the southwest face of Male Mountain.

A second, adjacent valley, drains Male Mountain's southeast flank, and a third flows in from the east, draining the south side of Female Mountain. From our vantage point we could scan all three valleys. In the second valley our counts ranged from 23 to 29 organ pipes for a mean of 25. In the third drainage, farthest from Orpi Valley, we saw only five, or possibly six, plants. In addition, we spotted about 15 organ pipes on the interior-facing slopes of the sea cliffs just south of Orpi Valley.

Our remaining effort focused on the middle section of Arroyo Limantour and its environs, where we assumed the second stand of organ pipes reported by Nabhan would be located. We spotted five plants widely scattered along the arroyo and possibly four more high on the adjacent mountain face, but we found no stand. We did observe four organ pipes in an entirely different locality, the steep arroyo behind the southwest corner of the island.

To summarize, our quick survey in 2001 showed that organ pipes are not as closely confined to Orpi Valley as we had thought. Rather, Orpi Valley seemed to be the center of concentration, with plants thinning out rapidly in all directions from there. As for the rest of the island, we saw no more than about 13 plants. These results reinforced our belief that organ pipes are common in the northwest corner, rare elsewhere, and virtually absent from the eastern half of the island.

Still More Hypotheses

Shortly after our trip, a chance conversation with William Peachey and Thomas Bethard generated a third and very compelling hypothesis (2001: pers. comm.). Peachey and Bethard have been documenting the relationship between organ pipes and lesser long-nosed bats (*Leptonycteris curasoae*) in the Sierra Pinacate, at the head of the Gulf. Here they discovered a deep cave that serves as a maternity roost for about 100,000 bats. These bats are apparently responsible for maintaining the organ pipe population in the region. Organ pipes will grow from seed in the Pinacate but the population does not appear to be self-maintaining. In late summer, bats make long foraging flights outside the Pinacate region and gorge on organ pipe fruit, ingesting the small seeds along with the pulp. On the return flight they typically defecate as they approach the roost. This deposits large numbers of seeds, which are capable of germinating if they receive sufficient moisture. Foraging vectors used by the bats are identifiable by lines of organ pipes converging on the Pinacate maternity roost.

By analogy, Peachey and Bethard suggested that the simplest explanation for the distribution of organ pipes on San Esteban, as we then understood it, would be that *Leptonycteris* bats are roosting below the northwest corner of the island and maintaining the population there. Like the Pinacate, San Esteban may be too arid for organ pipes reproduction. But bats foraging on Tiburón Island or the Sonoran mainland may be excreting organ pipe seeds over Orpi Valley and the surrounding landscape as they return to their roost. This would explain the concentration of plants in the northwest corner and the fact that plants of all ages occur there, since the process is presumably ongoing. In line with Felger's observation, Peachey and Bethard suggested that favorable microclimatic conditions in the northwest corner may provide the extra moisture needed for these seeds to germinate.

This scenario also made sense to Theodore Fleming, who has intensively studied *Leptonycteris* bats on the adjoining coast of Sonora (Sahley, Horner, and Fleming 1993; Fleming, Tuttle, and Horner 1996; Horner, Fleming, and Sahley 1998; Fleming, Maurice, and Hamrick 1998). Fleming and his colleagues have located day roosts near Bahía Kino and maternity roosts at the southern tip of Tiburón Island. Though nobody has looked on San Esteban, Fleming remarked that the island would be a logical place for a maternity roost because it would be safe from predators. Safety is the bats' main concern, even if it puts their food resources a long distance away (30 km or more is not unusual). As for specific locations, *Leptonycteris* bats will roost in a variety of natural cavities ranging from small crevices to large caves. Sea caves serve as important roosting sites farther south in Mexico (Ceballos and others 1997) and San Esteban has several such caves near the northwest corner. Hence Fleming saw nothing implausible about bats foraging on Tiburón or even the Sonoran mainland, returning to San Esteban and excreting organ pipe seeds in Orpi Valley before dropping over the sea cliffs to roosts in crevices or sea caves below (Theodore Fleming 2001: pers.comm.).

Appealing as this "Bat Hypothesis" was, it did not exhaust all possible explanations. An entirely different kind of hypothesis could be derived from the fact that San Esteban Island occupies a geographically marginal position within the broader distribution of organ pipes. This aspect of geography, coupled with climatic changes of the past century, suggested that San Esteban's organ pipes might be relicts – the last survivors of a larger population that has been dying out as the regional climate has become increasingly arid.

The specific basis for this "Relict Population Hypothesis" is the simple observation that, within the Midriff region, the northern and western limits of organ pipes are described by a right angle with San Esteban at its apex (Figure 4). In other words, in Baja California organ pipes occur only as far north as San Esteban Island, while on the Sonoran side they occur only as far west as San Esteban Island. The limiting factor on the plant's range is generally assumed to be summer rainfall. As one proceeds northwest up the Gulf from San Esteban, precipitation decreases and organ pipes vanish. This suggests that San Esteban, at the limits of the plant's range on two dimensions, must be a very difficult habitat, and that any reduction in moisture might be catastrophic. As Raymond Turner (1990) has shown for the

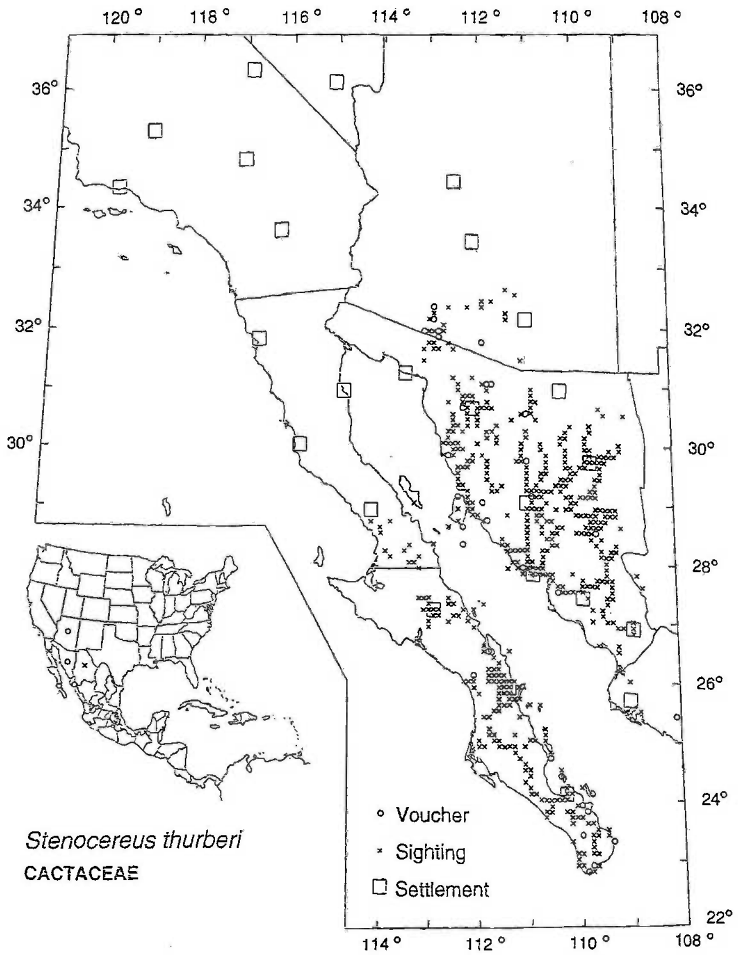


Figure 4. Distribution of organ pipe cactus in the Gulf of California region. (Reprinted from Turner, Bowers, and Burgess (1995: 381) by permission of The University of Arizona Press.)

Sierra Pinacate, short-term climatic fluctuations, measured in just two or three decades, can greatly alter local plant distributions, including those of columnar cacti.

There are no climatic records for San Esteban Island, and only spotty records for the surrounding region. On a hemispheric scale, the past century has been the warmest of the past millennium (Jones, Osborne, and Briffa 2001: 665), and parts of the Sonoran Desert are thought to be as hot and dry today as at any time during the Holocene (Van Devender 1990: 159). If this is true of the Midriff, it is possible that rainfall at some point in the recent past dropped below a critical threshold for organ pipes. That suggests in turn that San Esteban might once have supported a larger population, and that the plants we see today are a relict stand in the climatically-favored northwest corner, plus a few hardy individuals that have managed to hang on elsewhere. Judging by the rate at which one dying organ pipe decayed and partially disappeared during the 1980s (Figure 5), a rapid extirpation of organ pipes early in the last century would leave no trace today, and likely none even a decade or two after their death.

Coupled with this line of reasoning are possible early 20th century sightings of organ pipes on Ángel de la Guarda Island, northwest of San Esteban (Turner, Bowers, and Burgess 1995: 381). Could it be that this island too once had a population of organ pipes which, lying in a still drier section of the Gulf, has completely died off? I'll return to these anomalous sightings later.

We thus wound up with four loosely constructed and not mutually exclusive hypotheses. Though they might not be easily testable, all were based on the apparently skewed distribution of San Esteban's organ pipes. The first survey convinced us that the concentration in the northwest corner was real. For the next step, it seemed essential to be certain that plants were as scattered and rare on the rest of the island as we believed. Thus Larry Johnson, Patricia West, and I began planning a return trip.

The Second Orpi Hunt, April 2002

The second survey had four very specific objectives: First, to make an accurate determination of the abundance and distribution of organ pipes outside the northwest corner of the island. Secondly, to visit as many individual plants as possible and record enough information about each individual to characterize the population and provide a baseline data set. Thirdly, to revisit Orpi Valley to determine whether topography, soils, rock types, or other macroscopic characteristics could account for the concentration of organ pipes there. Unfortunately, the geologist who intended to help us with this had to drop out of the trip. Fourthly, to inspect caves for evidence of *Leptonycteris* bats, especially in the sea caves on the northwest side of the island.

What We Did

We spent six days searching for organ pipes. For four days we worked in the eastern half of the island. One day we circumnavigated the island by boat, inspecting the sea cliffs and shoreline visible from the sea. We used the sixth day to revisit Orpi Valley.

We conducted much of the search by remote scanning with binoculars. Generally, we hiked the drainage bottoms or terraces, stopping frequently to survey the surrounding landscape, and climbing knolls and small peaks to get a panoramic view. Most areas were scanned from at least two vantage points in order to spot plants hidden from one direction. We visited as many plants as was practical, about 44 percent of those recorded. We bypassed the remainder (many of which would have required long climbs) in order to maximize our areal coverage. All told, we surveyed about half the island.

We recorded only plants we could positively identify as organ pipes. Those not clearly distinguishable through binoculars could sometimes be positively identified with a 15X spotting scope. All plants not directly visited were confirmed by at least two of us, and in most cases by all three. This proved to be important, because we were surprised to discover that many young *Pitahaya agrias* closely mimic organ pipe growth form, branching from the base in the classic candelabra shape (Figure 6). At a distance their resemblance to young organ pipes is uncanny, and we took extra precautions to avoid recording these impostors.

Ours was obviously a minimum count – no doubt we missed some plants in the areas searched. This is especially likely for small plants, which are more prone to be hidden than large ones. But we found that even large plants are easy to miss. In one case, the pair of organ pipes we spotted in binoculars turned into a cluster of five within a 30 m radius (Plant Nos. 37-41) when we actually climbed up to them.

What We Found

We were astonished to discover that our fundamental assumption – that organ pipes are rare outside Orpi Valley and its environs – was dead wrong. Once we searched carefully, we found that they grow all over the island (Figure 3). In five days we recorded 57 plants outside the northwest corner. If we add to this figure the plants we observed outside the northwest corner in the 1980s and 2001, that figure increases to about 74. Since we counted approximately 100 plants in Orpi Valley and its surroundings, the total number of known organ pipes on San Esteban Island is approximately 174. Based on the number of plants we found outside the northwest corner, I estimate that there are about 30 more in areas we did not survey. And since small plants are especially hard to detect, the actual total is no doubt higher still. Thus a reasonable estimate for the island as a whole might be around 250 plants. Organ pipes may not be abundant on San Esteban, but we now know that they are not rare.

Of the 57 plants recorded in 2002, we visited 25 and observed the remaining 32 from varying distances. The specific data recorded for each plant are given in Appendix A. The present section summarizes those data and offers a few comparisons to the plants in Organ Pipe Cactus National Monument (OPCNM), which remains the only well-studied population. The limitations of samples as small as ours are obvious.

1. Height of Tallest Stem

Height (m)	Number of Plants (N=21)
< 1	1
1.1 - 2.0	3
2.1 - 3.0	6
3.1 - 4.0	7
4.1 - 5.0	3
> 5	1

Measured heights ranged from 0.7 m to 5.1 m (Figures 7 and 8). Following Parker (1987a: 298) we considered plants less than 2 m tall to be juveniles. Among plants observed only at a distance, we estimated that about 25 percent were less than 2 m tall, a figure roughly in line with the 19 percent of those plants actually measured.

The measured height classes form a rough approximation of a normal distribution. Since we probably missed seeing a disproportionate number of small plants, the true distribution likely includes many more young plants, suggesting the extent of recruitment is greater than our observations indicate.

2. Number of Stems

Stems	Number of Plants (N=27)
1-5	5
6-10	9
11-15	9
16-20	2
>20	2

3. Flower Buds

Flower Buds	Number of Plants (N=21)
Present	5
Absent	16

Three of the plants lacking flower buds are less than 2 m tall and hence are probably not reproductively mature. On the other hand, one plant 1.9 m tall is producing buds.

Buds were just beginning to appear at the time of our count. They were small and visible only at close range, so there was no chance of detecting them on distant plants. Organ pipes have a reproductive strategy that enables a small percentage of plants to bloom and set fruit earlier than the general population (Fleming 2000:436-37), and it may be that we only saw buds of these early bloomers.

4. Health

Health	Number of Plants (N=55)
Healthy	45
Sickly	5
Dead	5

The vast majority of plants (82%) appeared to be in good health, and many were positively robust. Three plants had one or more dead stems but appeared otherwise healthy.

5. Slope Angle

Angle	Number of Plants (N=55)
0° - 10°	8
11° - 20°	11
21° - 30°	17
31° - 40°	15
> 40°	4

As at OPCNM, organ pipes occur on flat ground but seem to prefer moderate slopes. San Esteban is predominantly mountainous, and any organism that wants to be widely distributed had better like rugged topography.

6. Slope Aspect

Aspect	Number of Plants (N=56)
N	7
NE	5
E	10
SE	9
S	6
SW	10
W	4
NW	5

About half again as many organ pipes are on south quadrant slopes (facing SE, S, or SW) as north quadrant slopes. Whether southern exposures are genuinely advantageous for organ pipes on San Esteban, as at OPCNM (Parker 1987b: 153-54), is unclear.

7. Elevation Above Local Drainage Channel

Elevation	Number of Plants (N=55)
< 1 m	5
1 - 5 m	3
6 - 10 m	3
11 - 50 m	15
51 - 100 m	17
> 100 m	12

These elevation figures should be regarded as only rough estimates. Because arroyos trap solar radiation during the day and receive cold air flow at night, plants at or near the bottom of drainage channels are subject to greater temperature extremes than those on the slopes above. We saw healthy organ pipes in arroyo bottoms, but these figures suggest they prefer slopes. As to absolute elevation, organ pipes occur from sea level to the summits of high peaks at 400 m or more.

8. Substrate

Substrate	Number of Plants (N=47)
Rocky soil	31
Talus	12
Arroyo gravel	2
Bedrock	2

Extensive talus slopes are common on San Esteban, but most of the island's surface consists of thin rocky soil. Coarse soils on steep slopes are derived from the island's volcanic rocks, while soil on gentler terrain often appears to be a fine loess blown in from elsewhere. Curiously, many organ pipes grow precisely where talus and rocky soil meet (Figure 9), and it is purely a judgement call as to which one is the plant's actual substrate. We also observed two plants rooted in fractured bedrock. Presumably both talus and cracks in bedrock are more effective than bare soil at providing shade and holding moisture, and thus may facilitate the germination of seedlings.

9. Nurse Plants or Rocks

Type	Number of Plants (N=27)
Plant	4
Rock or outcrop	2
None	21

We were reluctant to assign a nurse function to plants and rocks merely on the basis of proximity. Some of San Esteban's organ pipes are indeed entangled in plants or stand close to rocks or outcrops (including talus), but the same can be said for many other species. Moreover, many plants have seemingly thrived in complete isolation. Of course, it can be argued that some now-isolated organ pipes may have germinated under nurse plants that have subsequently died and disappeared, but there is no way of empirically evaluating this supposition.

At OPCNM, nurse plants and rocks optimize growth conditions for organ pipe seedlings in an otherwise marginal habitat (Parker 1987b: 153; 1988: 136). During the harsh winters, nurse plants reduce heat loss at night and may help retain moisture. South-facing nurse rocks or outcrops help prevent frost damage by acting as heat sinks, storing heat during the day and slowly releasing it at night, thereby creating a warmer microenvironment.

San Esteban Island, lying some 350 km south of OPCNM, at a lower elevation, and influenced by the moderating effect of the sea, is thought to be frost free. This is supported by the fact that we saw little evidence of stem constriction, a hallmark of frost damage at OPCNM. If nurse plants and rocks are important on San Esteban, their function would most likely be to provide shade and conserve moisture, as they do in Baja California (Nolasco, Vega-Villasante, and Diaz-Rondero 1997).

10. General Conclusion

One of Parker's chief conclusions for OPCNM was that the optimum habitats are southerly-facing (S, SE, and SW) middle and upper bajadas with slopes of 15° to 24° (Parker 1987b: 152-53; but see also Parker 1988: 133, 136). These conditions produced the greatest mean density of organ pipes and the highest rate of recruitment. Superficially, this would also seem to be true for San Esteban (assuming slopes of coarse rocky soil above arroyo bottoms to be the local equivalent of upper bajadas), but I suspect we would need much more comprehensive data, supported by statistical analysis, to demonstrate it.

Back to the Hypotheses

Now that we have counted some organ pipes, the real question is whether we have learned anything that enables us to discriminate among our four hypotheses. The answer is both yes and no.

The "Microclimatic Hypothesis" proposes that organ pipes are concentrated in Orpi Valley and the northwest corner because this area receives just enough extra moisture to allow organ pipes to flourish on this otherwise inhospitable island. Though we spent a day revisiting the northwest corner, this idea is difficult to evaluate. To judge by the sparse plant cover, the northwest corner in general seems, if anything, more arid than some other parts of the island. On the other hand, Orpi Valley itself may be slightly wetter, for annuals seem to be denser here than elsewhere. The valley is also quite brushy (Figure 1), containing much limberbush (*Jatropha cuneata*), elephant tree (*Bursera microphylla*), and jojoba (*Simmondsia chinensis*). All of these make good nurse plants for young organ pipes but, as elsewhere, many of Orpi Valley's organ pipes stand alone.

We were not able to identify any other factors to account for Orpi Valley's organ pipes. As far as we could tell from casual observation, the rock types and soils are typical and unremarkable. The valley is relatively deep, which might encourage sea fog to roll down it. Our sense is that whatever extra moisture reaches this valley must be slight. Perhaps in this arid environment, even a small increase is biologically important.

Thus the idea of extra moisture reaching Orpi Valley still seems reasonable, but as Patricia West notes (2001: pers. comm.), it is also possible that the concentration of organ pipes here is due more to chance factors than particular causes. And now that we know that plants exist in modest numbers elsewhere, maybe the Orpi Valley stand is less critical to understanding the distribution of San Esteban's organ pipes than we had thought.

In the "Placental Burial Hypothesis", Gary Nabhan suggests that Seris transplanting live cacti over buried placentas might have created disjunct plant populations, such as the Orpi Valley stand of organ pipes. Having found many more plants outside the northwest corner, it no longer seems reasonable to consider the Orpi Valley stand a disjunct population. However, it might be appropriate to consider all of San Esteban's organ pipes as a disjunct population. From this perspective, Seri placental burial, as Nabhan describes it, might explain how organ pipes were introduced to the island in the first place. It would also suggest a likely source, for organ pipes are common on the historic Seri stronghold of Tiburón Island, less than 12 km from San Esteban.

Perhaps the most important step in evaluating Nabhan's hypothesis would be to reconcile the discrepancies between his account of placental burial and the original Moser-Felger description of the practice. According to Felger and Moser, plants are simply buried with the placenta, not transplanted. This is a critical point, for simple burial would probably not generate new plants and therefore would not disperse them. The practice, as Felger and Moser describe it, would not be relevant to understanding the distribution of organ pipes on San Esteban.

The "Bat Hypothesis" proposes that *Leptonycteris* bats are maintaining the island's organ pipe population by excreting seeds as they return from overwater foraging flights to roosts in the cliffs below Orpi Valley. To evaluate this idea, we need to know three things: whether these bats frequent the island, whether they roost there, and whether the only organ pipe seeds that germinate are those carried in from elsewhere. Unfortunately, we struck out on all three counts.

Bats are a common sight on San Esteban, but these could be the resident fish-eating bat *Myotis vivesi* (Maya 1968) or possibly the California leaf-nosed bat *Macrotus californicus* (Case, Cody, and Ezcurra 2002: Appendix 12.3). *Leptonycteris* has not been reported on the island, but apparently nobody has looked for them, and we were not qualified to identify the bats we saw on the wing.

We inspected all the sea caves near the northwest corner but found no evidence of roosts. San Esteban is also riddled with small caves and crevices, many inaccessible to humans. These potential roosts are so numerous that we quickly realized the futility of making a systematic search of even the accessible ones.

We were on the island at the wrong season to determine whether organ pipes are self-recruiting. Although we saw buds on five plants, we don't know if they are setting fruit. If they are, the role of bats may be relatively minor.

In fact, judging by the situation in the Sierra Pinacate, if *Leptonycteris* bats do make use of San Esteban, their relationship with the island's plants might be vastly more complex than our simple scenario suggests. As William Peachey notes, (2002: pers. comm.), San Esteban's real attraction might be agave nectar. Paniculate agaves provide an important food resource for *Leptonycteris* bats (Hevly 1979; Howell 1979; Fleming, Nuñez, and Sternberg 1993), and the island has enormous stands of *Agave cerulata* spp. *dentiens*. It could be that they are foraging on San Esteban from roosts on Tiburón Island or the mainland, that they do not roost on San Esteban (except for night roosts), and that they are after agave (or cardón) nectar and have little or no interest in the organ pipes there.

The one hypothesis we can evaluate with some confidence is the "Relict Population Hypothesis", which maintains that San Esteban's organ pipes are dying off everywhere on the island except the climatically-favored Orpi Valley. This hypothesis predicts that plants outside the northwest corner should be rare and show evidence of stress. Instead, we found plants in respectable numbers and fine health. Apparently, the "Relict Population Hypothesis" is wrong.

Yet there is one nagging loose end tied to this hypothesis. That is the purported early 20th century sightings of organ pipes on Ángel de la Guarda, and possibly other Midriff islands, where none are known today. These enigmatic sightings have almost acquired the status of folklore. Turner, Bowers, and Burgess (1995: 381) attribute them to Ivan Johnston, who visited Ángel de la Guarda in 1921. Johnston uncharacteristically lumped his records of this plant without distinguishing individual islands, stating only that "On the peninsular side of the gulf this species was present on every island, with the sole exception of Catalina Island (which lies about 350 km south of the Midriff)" (Johnston 1924: 1111). Since the expedition visited all the larger Midriff islands from San Lorenzo to Ángel de la Guarda (Slevin 1923: 71-72), Johnston's statement, taken literally, implies that he saw organ pipes on San Lorenzo, San Lorenzo Norte, Salsipuedes, Rasa, and Partida, as well as Ángel de la Guarda. (Johnston did specifical record organ pipes on Tiburón Island but makes no mention of San Esteban).

Nobody is sure how to interpret Johnston's collective treatment of organ pipes. His field notes presumably list sightings on individual islands, but protracted efforts to locate those notes have come to naught. James Miller, Johnston's biographer, characterizes Johnston as a careful field worker. When pressed to speculate, Miller concluded that Johnston probably meant exactly what he said, which implies that he saw organ pipes on every Midriff island on the peninsular side, including Ángel de la Guarda (James Miller: pers. comm. 2001).

Reid Moran tracked down several references to organ pipes on Ángel de la Guarda (Moran 1983: 401). He notes that Howard Gentry listed the plant (Gentry 1949: 110) but that Gentry did not recall his source, and that Hastings, Turner, and Warren's atlas (1972: 134) listed it based on Gentry's citation. Moran also notes that Los Angeles collector Howard Gates casually mentioned seeing stunted organ pipe cacti on a trip to Ángel de la Guarda about 1936. In Gates's words (1946: 61), "So hot and dry is the island the great, giant *Pachycereus pringlei* and *Lemaireocereus thurberi* (i.e. *Stenocereus thurberi*) of the peninsula are here dwarfs, hardly recognisable (sic) as the same plants."

Moran acknowledges that Gates "knew his cacti", but wonders if his memory was correct. Moran himself visited Ángel de la Guarda ten times between 1952 and 1978 and never saw an organ pipe. The local fishermen he consulted told him they had not seen it there either, leading Moran to doubt the veracity of Gates's report (Moran 1983: 385, 401). Similarly, Jon Rebman attests to Gates's knowledge of cacti, but cautions that Gates once mentioned a beavertail cactus at Lake Chapala in Baja California, far out of its normal range. Rebman speculated that, if Gates's sighting on Ángel de la Guarda was real, it might be that Seris once introduced the plant and that perhaps a few plants, gone now, survived there out of their normal range long enough for Gates to see them (Jon Rebman: pers. comm. 2001).

If organ pipes were once common on Ángel de la Guarda, it might help explain the baffling abundance of archaeological remains on this nearly waterless island. The 18th century Jesuit missionaries in Baja California wrote that the liquid in organ pipe fruit could suffice for a time as a water substitute, enabling the local Cochimí Indians to temporarily exploit waterless and hence otherwise uninhabitable localities (Aschmann 1967: 58-61).

A Little Heresy

If San Esteban Island is perfectly good habitat for organ pipes, as our 2002 survey suggests, then why is the population so small and scattered? One hypothesis that would account for their relatively small numbers is that organ pipes were introduced to the island only recently, and that they are still in the process of filling the niche. If so, how might they have gotten to San Esteban in the first place, and when?

One way is by "natural" agents of dispersal. Bats and birds eating the fruit on Tiburón Island, the Sonoran mainland, or Baja California could have carried the seeds to San Esteban Island, and done so only recently. While this is a straightforward and simple explanation, one cannot help wondering why the plant would not have been introduced long ago, resulting in a larger population today. The orthodox answer, that introductions are essentially random with respect to time and hence as likely to be recent as ancient, is no doubt correct, but ultimately not very satisfying. Could there be another explanation?

Figure 5. Dying organ pipe near the summit of Pico Rojo, looking east northeast. (January 1981, TB)

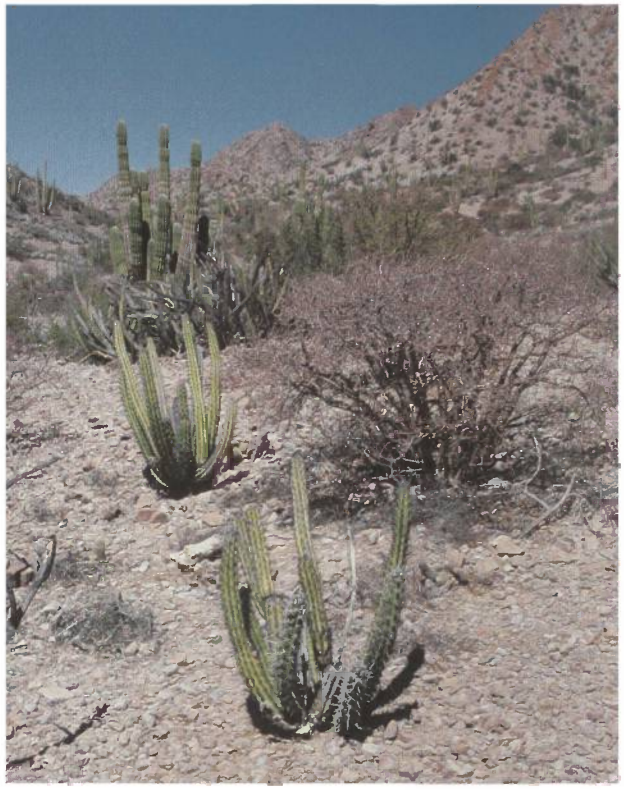


Figure 6. Orpi wannabees. Two young *Pithaya agrias* mimic the growth habit of organ pipes. As they mature, they will adopt the dense creeping and sprawling form normally associated with this plant (as has the individual in front of the cardón). (April 2002 TB)

Figure 7. Plant No. 2 (left), the smallest organ pipe encountered during the April 2002 survey. It is a single stem 0.7 m tall. Photo looks northwest. (April 2002, TB)

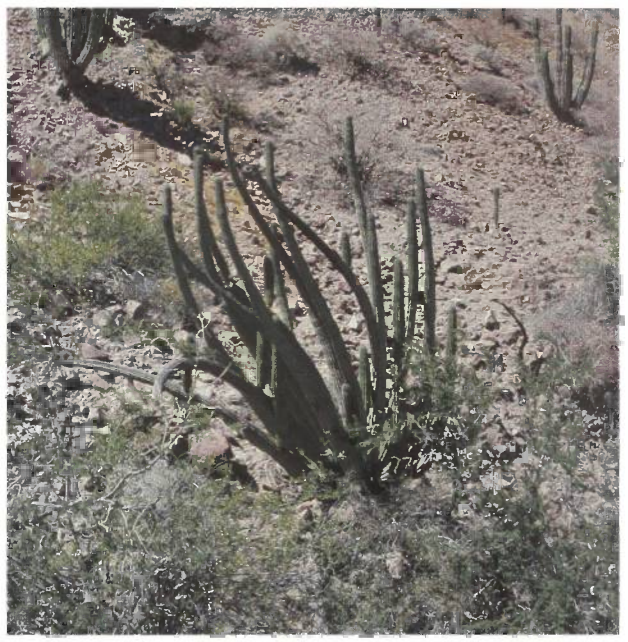


Figure 8. Plant No. 29, the largest organ pipe visited during the April 2002 survey. It is 5.1 m tall and has 29 stems. It is located at the junction of an arroyo terrace and the east-facing rocky slope above, about 5m above the bottom of one of the island's major drainage channels. Photo looks northwest. (April 2002, TB)

In fact, it is equally straightforward and simple to suppose that the dispersal agents were humans. This brings us back to Nabhan's thesis that Seri Indians or their ancestors might have intentionally dispersed a number of native plants and animals within the upper Gulf region. Though Nabhan implies a connection between organ pipes and placental burial, the mechanism could have been even simpler. Seris might have introduced the plants by seed rather than transplant, and this could have happened unintentionally. It is easy to construct a plausible scenario of how this might have happened.

Organ pipe seeds are contained in the fruit in large numbers, averaging close to 2000 per fruit. Since they are small they are routinely consumed with the pulp by birds, bats, and Seris alike. They must be free of pulp to germinate (McDonough 1964: 155), but once cleaned, as is the case after a trip through a digestive tract, the germination rate can be as high as 88 percent, given ideal temperature and moisture conditions (Parker 1987a: 299).

The Seris say that before the 1920s organ pipe fruit was usually not eaten directly but was mashed, fermented, and consumed as wine (Felger and Moser 1974: 268; 1985: 247, 259). The fruit, gathered on Tiburón, might either have been fermented and drunk there or carried across the channel intact and made into wine on San Esteban. Either way, people probably ingested a large number of seeds with the wine, for Seris do not normally strain liquids to remove particulate matter (Mary Beck Moser 2002: pers. comm.; Richard Felger 2002: pers. comm.). Hence Seri travellers could easily have consumed wine on Tiburón Island and excreted the seeds on San Esteban a day later. Once a few plants were established, seeds from the founding population would have been further dispersed throughout the island by birds and bats as well as by Seris. Birds and bats have presumably continued this process to the present.

One of the appealing aspects of this scenario is that we can specify who the people introducing the plant likely were and when the introduction likely took place. Through the combined sources of Seri oral history, the Euroamerican documentary record, and the archaeological record, it has been possible to reconstruct something of San Esteban Island's cultural history. Although the island may have been occasionally visited for thousands of years, it remained uninhabited until post-Spanish times. The people who eventually moved there were a small group of Seris who were pushed off Tiburón Island by mainland Seris fleeing to Tiburón to escape European military persecution. Exactly when this displacement occurred is uncertain, but the best guess is the late 18th century. If so, the San Esteban people, as these Seris became known, lived on the island only about a hundred years. Late in the 19th century these reclusive folk were apparently rounded up and exterminated by Mexican soldiers (Moser 1963: 25-26; Bowen 2000: 437-41).

The San Esteban people would have been thoroughly familiar with organ pipe cactus before they were pushed off Tiburón Island. They undoubtedly remained familiar with the plant, for they often paddled from San Esteban to Tiburón Island, and the Seris who replaced them on Tiburón sometimes paddled over to San Esteban for visits. Thus throughout the 19th century, there would have been multiple opportunities for travelling Seris to consume organ pipe fruit from Tiburón (presumably as wine) and deposit the seeds on San Esteban.

Whatever the precise mechanism, a late 18th or 19th century introduction of organ pipes to the island by historic Seris seems consistent with the population's sparse but more or less island-wide distribution, good health, and (apparently) successful recruitment. It might also explain why organ pipes were not discovered by botanists until the mid-20th century, for if they are recent introductions and are still in the process of expanding their numbers, they may, in fact, have been rare plants until quite recently.

What this scenario does not specifically account for is the modest concentration of plants in the Orpi Valley area. Also, as a hypothesis it would be difficult to test in its entirety. Mitochondrial DNA analysis might establish Tiburón Island as the source of San Esteban's organ pipe population. But it is hard to imagine how humans could be unambiguously distinguished from bats and birds as the agents of dispersal, or how introduction by seed could be distinguished from introduction by transplant.

Looking farther afield, the idea of Seri dispersal might explain why there are no organ pipes on San Lorenzo Island. San Lorenzo lies midway between San Esteban, where there are organ pipes, and Baja California, where there are also organ pipes (Figures 2 and 4). There is nothing obvious about San Lorenzo's topography, rock types, or soils that would preclude the plant. Cody et al. (2002: 92)) attribute their absence to less annual rainfall on San Lorenzo than on Tiburón and San Esteban, but their own isohyets (2002: Fig. 4.1) indicate similar annual precipitation for all three islands, as well as the adjacent portion of the peninsula where organ pipes occur (Turner, Bowers, and Burgess 1995: 381). Much more important is summer rainfall, and San Lorenzo receives less than does Tiburón and the Sonoran mainland. But here again Cody et al. (2002: Fig 4.3) indicate that San Lorenzo receives as much or more than San Esteban and the adjacent portion of Baja California, where organ pipes unquestionably occur. While their precipitation figures are admittedly imprecise (Codyet al. 2002: 65), on the face of it San Lorenzo's lack of organ pipes would appear to be due to something other than climate. Could it be that organ pipes are missing from San Lorenzo simply because nobody introduced them there?

While this idea may be heresy in conventional biogeographical thinking, it is consistent with what we know of the human use of San Lorenzo. In sharp contrast to Tiburón, San Esteban, and the adjacent shores of both Baja California and mainland Sonora, San Lorenzo has few archaeological remains (Bowen 2000: 471-72), which indicates that humans were never more than temporary visitors there. The only indigenous people we know of who went there were the San Esteban people. According to Seri oral history, these folk often paddled from San Esteban to San Lorenzo, and it is said that one group actually lived there for a whole year (Bowen 2000: 23). But if organ pipes were just being introduced to San Esteban during that time, there would have been few plants on San Esteban and even fewer, if any, fruits. The probability of anyone consuming fruit or wine on San Esteban and depositing the seeds on San Lorenzo would have been close to zero.

The concept of overwater dispersal of native plants and animals by humans in the Midriff is not new (Shaw 1946; Lowe and Norris 1955; Grismer 1994; see also Yetman and Búrquez 1996; Bahre and Bourillón 2002; Mellink 2002). If anyone still recoils at the very idea of humans as agents of dispersal, I would point out that one of the truly great themes in human history worldwide – one intricately documented by archaeologists – has been the deliberate translocation of useful plants and animals and the inadvertent dispersal of others. Proof of this is as simple as a glance at the menu of any American coffee shop or a consideration of the global problem of invasive exotic species (e.g. Tellman 2002). The idea of moving plants and animals to new locations is simple and obvious, and pragmatic hunting and gathering peoples like the Seris and Cochimís have long understood the biological requirements of familiar organisms. It is worth remembering that even the world's plant and animal domesticates were once "native" species, that it was hunting and gathering peoples who first expanded their ranges, and that this entire process has taken place just within the past 11,000 years.

Archaeological evidence shows clearly that humans had arrived in the Midriff region, and may have begun visiting the islands, by 11,000 years ago (Robles and Manzo 1972; Bowen 1976: 89-91; 2000: 390-94; Hyland 1997: 387-88; Bahre and Bourillón 2002). Thus there is no doubt that people were available to help with the great reshuffling of Gulf flora and fauna that took place as the climate changed from Plleistocene to Holocene conditions. Given what we know of humans elsewhere, it would be astonishing if they did not play some role in this process in the Midriff, and there is no reason why their participation should not have extended into historic times. Wind, bats, birds, and rafts of detritus have undoubtedly been important agents of overwater dispersal since time immemorial, but for the post-Pleistocene period, humans have by far the best track record the world over.

Now What?

Whatever role humans may have had in introducing organ pipes to San Esteban, it is certain that humans are neither maintaining nor further dispersing the population today. And with that statement, I have related the story far as it presently goes. Whether this tale will eventually be brought to a proper conclusion remains to be seen, but the ending will have to be written by a biologist – someone with the expertise to see where the plot might lead from here. For whomever is willing to take up the story, I hope that pursuit is as much fun as it has been so far, and I wish them every success in figuring out the ending.

Thanks!

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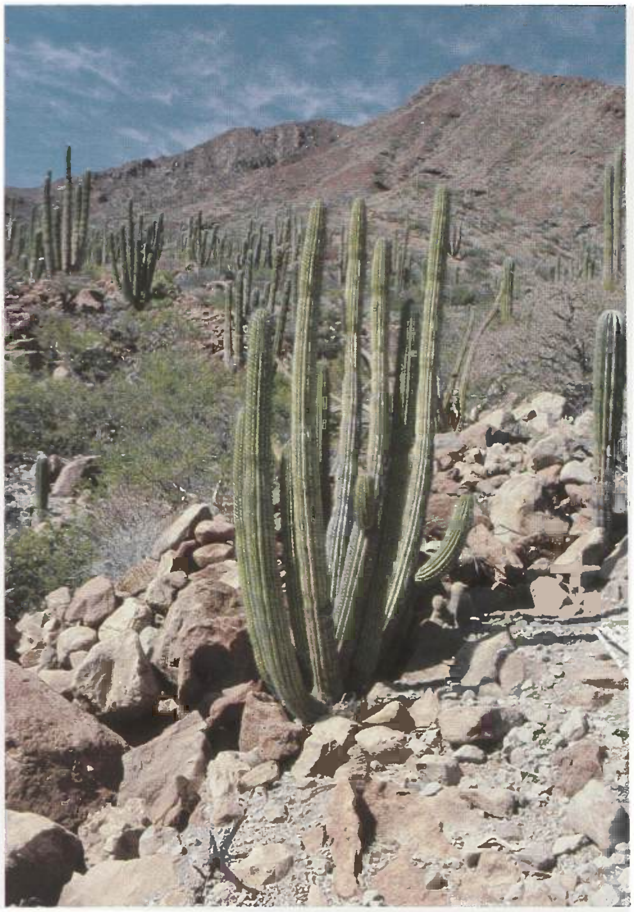

Figure 9. Plant No. 7, situated at the boundary between a talus slope (behind the plant) and the island's characteristic rocky soil (foreground). Photo looks north. (April 2002, TB)

Appendix A

Data for Individual Plants

Plant no. Nurse	Visit	Ht. (m)	No. stems	Buds	Health	Slope Angle (deg)	Slope Aspect	Approx. elevation above drainage		Substrate
1	Yes	3.8	13	No	Healthy	>40	E	15	RS[1]	No
2	Yes	0.7	1	No	Healthy	>40	E	15	RS	No
3	Yes	2.8	18	No	Healthy	11-20	SW	100	T[2]	No
4	Yes	3.9	8[3]	No	Sickly	11-20	SE	100	T	No
5	Yes	1.1	3	No	Healthy	11-20	SW	100	RS	No
6	Yes	1.9	7	Yes	Healthy	11-20	NW	100	T	No
7	Yes	2.7	11	No	Healthy	11-20	SW	100	RS	No
8	Yes	3.8	13[4]	Yes	Healthy	11-20	SW	250	T	No
9	Yes	1.9	8	No	Sickly	21-30	SW	80	RS	No
10	Yes	2.9	8	No	Healthy	11-20	SW	50	RS	Plant
11	No	A[5]	7+[6]		Healthy	0-10	E	0		
12	No	A	7+		Sickly	0-10	E	0	AG[7]	
13	No	A	8+		Healthy	0-10	SE			
14	No	A	10+		Healthy	21-30	NW	50		
15	No	J[8]	2+			>40?	S	300		Plant
16		A	8+		Healthy	11-20	SW	200		Plant
17	No	A	7+		Healthy	31-40	SE	20	T	
18	No	A	3+		Healthy	31-40	S	200		No
19	No	A	5+		Healthy	31-40	S	200		No
20	No	A	5+		Healthy	31-40	S	200		No
21	Yes	3.8	7	No	Healthy	11-20	N	5	T	No
22	No	A	11+		Healthy	31-40	S	200	T	Plant
23	Yes	2.9	14	No	Healthy	0-10	S	30	RS	No
24	No	A	7+		Healthy	11-20	NE	0	RS	No
25	Yes	4.5	27	No	Healthy	31-40	SE	50	RS	No
26	Yes	3.0	11	No	Healthy	31-40	SE	50	RS	No
27										
28	No	A	7+		Healthy	31-40	W	20	RS	
29[9]	Yes	5.1	29	Yes	Healthy	21-30	E	5	RS	No
30	No	A	11			21-30	NE	120	RS	
31	No	A	7+		Sickly	21-30	NE	100	RS	
32	No	J	3		Healthy	0-10	E		RS	No
33	Yes	J			Healthy	21-30	NW	8	T	No
34	No	A	6+		Healthy	21-30	NE	10	RS	
35	No	A	5+		Healthy	21-30	SE	50	RS	
36	No	J	4+		Healthy	31-40	SE	100	T	
37[10]	Yes	A	10	No	Dead	21-30	N	100	RS	
38	Yes	2.8	7[11]	Yes	Healthy	21-30	N	100	RS	
39[12]	Yes			No	Dead	21-30	N	100	RS	
40	Yes	4.7	12[13]	Yes	Healthy	21-30	N	100	RS	
41[14]	Yes	4.8	12	No	Dead	21-30	N	100	RS	
42	No	J	3+		Healthy			40	RS	
43[15]	Yes	3.5	20	No	Dead	0-10	E	5	RS	
44	No	A	6+		Healthy		NE	30		
45	No	J	9		Sickly	21-30	SW	30	RS	
46	No	J	3+		Healthy	21-30	W	30	RS	
47	Yes	3.7	9		Healthy	0-10	W	0	T	
48[16]	No	A	11+		Healthy	21-30	NW	100		
49	No	J	5		Healthy	>40	NW	50	BR[17]	
50	No	A	5+		Healthy	31-40	E	250	T	
51	No	A	7+		Healthy	31-40	SE	200	T	Rock
52	No	J	4+		Healthy	31-40	SW	100	BR	Rock
53	No	A	6+		Healthy	31-40	SW	200	RS	
54	No	A	5+		Healthy	31-40	SE	100	RS	
55	No	A	6+		Healthy	31-40	E	100	RS	
56	Yes	A	13		Healthy	31-40	N	10	RS	
57	No	A	15+		Dead	31-40	W	0	AG	
58	Yes	3.7	4		Healthy	31-40	E	150	RS	No

Key
1. RS = rocky soil
2. T = talus
3. One stem is dead, one is a skeleton, and two are discolored brown
4. Three stems are skeletons
5. A = adult plant, >2 m tall. Heights of plants not visited could not be more accurately estimated from a distance.
6. Plus signs (+) indicate that additional stems may have been hidden from view. For plants observed only from a distance, it was seldom possible to be sure we counted every stem. Hence figures with plus signs are minimum numbers.
7. AG = arroyo gravel
8. J = juvenile plant, <2 m tall. Heights of plants seen only at a distance could not be estimated more accurately.
9. This plant was seen in 1980.
10. A standing skeleton.
11. One stem is a skeleton.
12. A fallen skeleton
13. Five stems are skeletons but plant is otherwise healthy.
14. A standing skeleton.
15. The plant, alive and healthy in 1980, is now a fallen skeleton.
16. This plant was seen in 1981.
17. BR = bedrock
18. Still standing, but mostly or completely reduced to a skeleton

Corrected "Appendix A" for Organ Pipes (Bowen) Vol. 19, No. 1, p. 28 (2003)

Appendix A   Data for Individual Plants

Plant No.	Visited	Ht. (m)	No. Stems	Buds	Health	Slope Angle (deg.)	Slope Aspect	Approx. Elev. (m) Above Drainage	Sub-Strate	Nurse
1	Yes	3.8	13	No	Healthy	>40	E	15	RS[1]	No
2	Yes	0.7	1	No	Healthy	>40	E	15	RS	No
3	Yes	2.8	18	No	Healthy	11-20	SW	100	T[2]	No
4	Yes	3.9	8[3]	No	Sickly	11-20	SE	100	T	No
5	Yes	1.1	3	No	Healthy	11-20	SW	100	RS	No
6	Yes	1.9	7	Yes	Healthy	11-20	NW	100	T	No
7	Yes	2.7	11	No	Healthy	11-20	SW	100	RS	No
8	Yes	3.8	13[4]	Yes	Healthy	11-20	SW	250	T	No
9	Yes	1.9	8	No	Sickly	21-30	SW	80	RS	No
10	Yes	2.9	8	No	Healthy	11-20	SW	50	RS	Plant
11	No	A[5]	7+[6]		Healthy	0-10	E	0		
12	No	A	7+		Sickly	0-10	E	0	AG[7]	
13	No	A	8+		Healthy	0-10	SE			
14	No	A	10+		Healthy	21-30	NW	50		
15	No	J[8]	2+			>40?	S	300		Plant
16		A	8+		Healthy	11-20	SW	200		Plant
17	No	A	7+		Healthy	31-40	SE	20	T	
18	No	A	3+		Healthy	31-40	S	200		No
19	No	A	5+		Healthy	31-40	S	200		No
20	No	A	5+		Healthy	31-40	S	200		No
21	Yes	3.8	7	No	Healthy	11-20	N	5	T	No
22	No	A	11+		Healthy	31-40	S	200	T	Plant
23	Yes	2.9	14	No	Healthy	0-10	S	30	RS	No
24	No	A	7+		Healthy	11-20	NE	0	RS	No
25	Yes	4.5	27	No	Healthy	31-40	SE	50	RS	No
26	Yes	3.0	11	No	Healthy	31-40	SE	50	RS	No
27	[NO DATA RECORDED]									
28	No	A	7+		Healthy	31-40	W	20	RS	
29[9]	Yes	5.1	29	Yes	Healthy	21-30	E	5	RS	No
30	No	A	11			21-30	NE	120	RS	
31	No	A	7+		Sickly	21-30	NE	100	RS	
32	No	J	3		Healthy	0-10	E		RS	No
33	Yes	J			Healthy	21-30	NW	8	T	No
34	No	A	6+		Healthy	21-30	NE	10	RS	
35	No	A	5+		Healthy	21-30	SE	50	RS	
36	No	J	4+		Healthy	31-40	SE	100	T	
37[10]	Yes	A	10	No	Dead	21-30	N	100	RS	
38	Yes	2.8	7[11]	Yes	Healthy	21-30	N	100	RS	
39[12]	Yes			No	Dead	21-30	N	100	RS	
40	Yes	4.7	12[13]	Yes	Healthy	21-30	N	100	RS	
41[14]	Yes	4.8	12	No	Dead	21-30	N	100	RS	
42	No	J	3+		Healthy			40	RS	
43[15]	Yes	3.5	20	No	Dead	0-10	E	5	RS	
44	No	A	6+		Healthy		NE	30		
45	No	J	9		Sickly	21-30	SW	30	RS	
46	No	J	3+		Healthy	21-30	W	30	RS	
47	Yes	3.7	9		Healthy	0-10	W	0	T	
48[16]	No	A	11+		Healthy	21-30	NW	100		
49	No	J	5		Healthy	>40	NW	50	BR[17]	
50	No	A	5+		Healthy	31-40	E	250	T	
51	No	A	7+		Healthy	31-40	SE	200	T	Rock
52	No	J	4+		Healthy	31-40	SW	100	BR	Rock
53	No	A	6+		Healthy	31-40	SW	200	RS	
54	No	A	5+		Healthy	31-40	SE	100	RS	
55	No	A	6+		Healthy	31-40	E	100	RS	
56	Yes	A	13		Healthy	21-30	N	10	RS	
57[18]	No	A	15+		Dead	11-20	W	0	AG	
58	Yes	3.7	4		Healthy	0-10	E	150	RS	No

Key

1. RS = rocky soil.
2. T = talus.
3. One stem is dead, one is a skeleton, and two are discolored brown.
4. Three stems are skeletons.
5. A = adult plant, >2m. tall. Heights of plants not visited could not be more accurately estimated from a distance.
6. Plus signs (+) indicate that additional stems may have been hidden from view. For plants observed only from a distance, it was seldom possible to be sure we counted every stem. Hence figures with plus signs are minimum numbers.
7. AG = arroyo gravel.
8. J = juvenile plant, <2m. tall. Heights of plants seen only at a distance could not be estimated more accurately.
9. This plant was seen in 1980.
10. A standing skeleton.
11. One stem is a skeleton.
12. A fallen skeleton.
13. Five stems are skeletons but plant is otherwise healthy.
14. A standing skeleton.
15. This plant, alive and healthy in 1980, is now a fallen skeleton.
16. This plant was seen in 1981.
17. BR = bedrock.
18. Still standing, but mostly or completely reduced to a skeleton.

Propagation of *Taxodium mucronatum* from Softwood Cuttings

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Abstract
Mexican bald cypress (*Taxodium mucronatum* Ten.) is propagated from seed, but procedures have not been reported for the propagation of this ornamental tree by stem cuttings. This study evaluated the use of softwood cuttings to propagate Mexican bald cypress. Softwood cuttings were collected on 16 October 1998 and 1999 from Las Cruces and Los Lunas, New Mexico, treated with either 3000 or 8000 ppm of indole-3-butyric acid (IBA) and held under intermittent mist in a greenhouse for 13 weeks. In 1998, cuttings sampled from one of two Los Lunas trees showed 48% and 82% rooting when treated with IBA at 3000 or 8000 ppm, respectively. Root number and average root length were 9 and 3 times greater, respectively, with 8000 ppm IBA than with 3000 ppm IBA. More 1998 cuttings rooted (65%) than 1999 cuttings (10%) when means were combined over IBA treatments. Results indicate that efficient propagation of Mexican bald cypress by cuttings depends on exogenous IBA and selection of stock plants amenable to root formation.

Introduction
Mexican bald cypress or Montezuma cypress (*Taxodium mucronatum* Ten.) is a deciduous conifer that was distributed across the northern hemisphere but is now limited to Mexico, southern Texas and Guatemala. The plant may be a geographical form of the common bald cypress (*Taxodium distichum* L.) (Harper, 1902), but Debreczy and Rácz (1998) reported that trees of Mexican bald cypress are more compact, have smaller cones (0.6 to 1 inch diameter) with pointed scales and shorter leaves (0.2 to 0.5 inch long) than its northern relative, the bald cypress. Additionally, St. Hilaire (2001) reported that Mexican bald cypress lacks the distinctive root collar swellings (pneumatophores) that are characteristic of *T. distichum*.

Mexican bald cypress typically may be propagated from seed (St. Hilaire, 2001), but asexual propagation techniques are not well established. Softwood cuttings have been used to propagate *T. distichum* (Moore, 1970), but there are no reports of whether softwood cuttings may be used to propagate *T. mucronatum*. In view of the declining range of the plant, initial and the lack of clonal propagation-related data, the objective of this research was to evaluate whether softwood cuttings could be used to propagate Mexican bald cypress.

Terminal softwood cuttings were collected on 16 October 1998 and 1999. Cuttings were selected from the lower branches of an 11-year-old tree at New Mexico State University's Fabian Garcia Science Center in Las Cruces (lat. 32° 16' 48" N; long. 106° 45' 18" W), from all branches of a 2-year-old tree at an arboretum in Los Lunas, New Mexico (lat. 34° 48' 18" N; long. 106° 43' 42" W), and from all branches of a 2-year-old tree in the display landscape of a nursery in Los Lunas. Plants of *T. mucronatum* grow rapidly. The 11-year-old tree was 12 m tall (≈50 main branches), and the 2-year-old trees had reached 2 m (≈ 15 main branches). This facilitated the collection of at least 30 terminal cuttings per tree in each of the two years. All trees were irrigated as necessary, but not fertilized. In addition, all trees originated as seedlings from two adjacent, open-pollinated, trees in a stand located in the Gila National Forest. Cuttings were collected at sunrise at the Los Lunas locations and late morning at the Las Cruces site. Harvested cuttings from all provenances were misted immediately, sealed in opaque plastic bags, and kept on ice. Cuttings selected from the Los Lunas locations were transported (H"2 hours) to Las Cruces. Both collections were stored at 10 C overnight in a refrigerator. In the early morning of 17 October 1998 and 1999, the cuttings were removed randomly from the bags and their basal ends recut to obtain terminal cuttings that were 15 cm long. Basal diameter of cuttings ranged from 3 to 5 mm. The basal 1.5 cm on opposite ends of the cutting was wounded by scraping off the epidermis and phloem with a razor blade. The wounded area was coated with talc containing 3000 or 8000 $mg•kg^{-1}$ IBA (Hormodin® #2 or #3, E. C. Geiger, Harleysville, PA.). The basal cutting ends then were inserted 5 cm deep into 10-cm tall × 35-cm wide × 50-cm deep plastic flats (Dyna-flat™, A. H. Hummert, Earth City, Mo.) containing 1:1 coarse perlite : peat moss by volume. Holes were drilled on the bottom surfaces of the flats to facilitate drainage. There were 30 cuttings in each of five flats. A single cutting was the experimental unit. In each of two years, the experiment was completely randomized with three tree sources, two levels of IBA, and 25 replications for each source x IBA combination.

Flats were placed in a propagation bench (30% shade) and misted with tap water 6 sec every 6 min from 0800 to 1800 HR. Daily minimum/maximum temperatures of the air within the mist bench were 15 ± 2/35 ± 5 C in 1998-1999 and 13 ± 3/35 ±4 C in 1999-2000. Midday photosynthetically active radiation averaged 326 ± 126 $\mu mol•m^{-2}•s^{-1}$ in 1998-1999, and 280 ± 84 $\mu mol•m^{-2}•s^{-1}$ in 1999-2000.

Cuttings were destructively harvested after 13 weeks (14 January 1999 and 2000). Adventitious roots that protruded more than 2 mm from the sides of each cutting were counted, and their lengths were measured. The root lengths on each were analyzed to test whether the year of propagation affected rooting performance.

Results and Discussion

In both years, cuttings that rooted were from the 2-year old tree in the display landscape of the Los Lunas nursery. Within each year, the level of IBA did not affect rooting percentage, but more 1998 cuttings rooted (average of 65%) than 1999 cuttings (average of 10%) (Table 1). Cuttings selected in 1999 may not have rooted successfully because they were one year older than those selected in 1998. This is consistent with a report by Moore (1970) that has shown the age of the stock plant influences rooting of its northern relative, *T. distichum*.

For cuttings propagated in 1998, root number and mean root length were 9 and 3 times greater, respectively, with 8000 ppm IBA than with 3000 ppm IBA (Table 1). In addition, root dry weights were 15 times higher in cuttings treated with IBA at 8000 ppm than in cuttings treated with IBA at 3000 ppm (Table 1), thus indicating that the higher level of IBA was more effective in promoting adventitious rooting. Environmental conditions were similar and cuttings were selected on the same date for both repetitions of the experiment. Yet, the level of IBA did not affect root number, mean root length and root dry weight of cuttings selected in 1999 (Table 1). Although several factors affect root formation in stem cuttings (St. Hilaire and Fierro, 2000), these results suggest that the inconsistency in rooting Mexican bald cypress from year to year may be related to the age of the stock plants.

Acknowledgements

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Table 1. Percentage rooting, number of primary roots, mean root length, and root dry weight of cuttings taken from a 2-year-old tree of Mexican bald cypress in the display landscape of a nursery in Los Lunas, New Mexico. Cuttings were collected on 17 October 1998 and 1999, treated with IBA at 3000 or 8000 ppm, and propagated for 13 weeks.

IBA	Rooting (%)		No. of primary roots		Mean root length (mm)		Root dry wt. (mg)	
(ppm)	1998	1999	1998	1999	1998	1999	1998	1999
3000	48[z] a	4 a	1 a	0.04 a	6 a	0.22 a	4 a	0[y] a
8000	82 a	16 a	9 b	0.24 a	18 b	1.28 a	59 b	0.2 a

[z]Means within columns were separated by $LSD_{0.05}$. Each value is the mean of 25 values.
[y]Weight was too low to detect.

Distribution of the Exotic Mustard *Brassica tournefortii* in the Mohawk Dunes and Mountains, Arizona

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Abstract
Ample winter-spring rains in southwestern Arizona in early 2001 allowed us to map the range of the exotic *Brassica tournefortii* in the Mohawk Sand Dunes. The mustard has colonized habitat ranging from creosote flats to dune crests, but it is most successful along ephemeral watercourses, the base of north-facing dunes, and along roads. An estimated 80-90% of the Mohawk Dunes, in both the Mohawk Valley and San Cristobal Valley, are host to *B. tournefortii,* with only the southernmost portion of the dunes uncolonized. Outside of the dunes, the mustard was found largely along roads frequented by the Border Patrol.

Resumen
Lluvias adecuadas desde invierno a primavera en el suroeste de Arizona en la primera parte de 2001 nos permite hacer mapas del exótico *Brassica tournerfortii* de las Mohawk Sand Dunes. La mostaza ha colonizado el terreno desde los llanos de creosote hasta la cumbre de las dunas. Sin embargo los que mejor crecen son los de arroyos efémiros, los de la base hacia las dunas, y los de las rutas y caminos. Se estima que un 80% - 90% de las Mohawk Dunes, en ambos el Mohawk Valley y el San Cristobal Valley contiene *B. tournerfortii* tan solo una porción de las dunas de la parte del sur sin colonizar. Fuera de las dunas la mostaza se encuentra majormente por las rutas y caminos frecuentados por la partrulla fronteriza.

There is not a single permanent human habitation in the 1.6 million acres of desert that make up the Barry M. Goldwater Air Force Range of southwestern Arizona. There are, however, plenty of visitors: the U.S. military and the Border Patrol, citizens seeking a bit of arid solitude, and job seekers from Latin America. The conflict between preserving a "natural" state for the Goldwater, while at the same time temporarily occupying it, is illustrated by the spread of the exotic mustard, *Brassica tournefortii* Guoan.

There are over three thousand species of mustards worldwide. Only a dozen or so inhabit this most arid corner of Arizona (Felger 1998, 2000), yet after a cool season rain the mustards appear to cover the Sonoran Desert. If you're walking out in the creosote flats or across the bajadas, you'll see native mustards like bladderpod and peppergrass. However, if you're driving along Interstate 8 in southern Arizona or California, you'll mostly see *B. tournefortii*.

Variously known as Sahara mustard, Asian mustard, Moroccan mustard, African mustard, wild turnip, or mostaza, *B. tournefortii* is an invasive weed, particularly of sandy and disturbed areas (Minnich and Sanders, 2000). It is a native of the Old World, where it ranges from northern India to the Iberian Penisula in a strip that encompasses the Caspian Sea, Mediterranean Europe, the Middle East and North Africa (Prakash 1974; Thanos et al. 1991). Within the United States, it was first collected at Coachella in southeastern California in 1927 (Minnich and Sanders, 2000), and has since spread to seven California counties: San Diego, Imperial, Riverside, San Bernardino, Kern, Santa Barbara, and, as of 1998, Shasta County (www.CalFlora.org). It is also in Texas, Nevada, and, since at least 1957, Arizona (USDA, NRCS, 2001; Mason 1960). It reaches into Mexico, ranging from Baja California to the Rio Grande/Rio Bravo Valley along the international border, and as far south as the Rio Mayo of Sonora (Felger 2000; Johnston 1990). Within Arizona its distribution is not formally mapped, but various floras, herbarium records and personal observations show *B. tournefortii* in Pima, Pinal, Yuma, La Paz, Maricopa, and Mohave counties.

The spread of *B. tournefortii* has provoked California to brand it "A-2," a category reserved for the "Most Invasive Wildland Pest Plants" (CalEPPC 1999). *B. tournefortii* has caused equal alarm among land managers in Arizona who hope to maintain the native biota. This study provides the baseline data needed to assess the velocity of *B. tournefortii* colonization in and around the Mohawk Dunes on the Goldwater Air Force Range, and to determine areas that are still free of *B. tournefortii* and thereby suitable for pre-invasion data collection of community composition.

Methods
The Mohawk Mountains and Mohawk Sand Dunes are about forty-five miles east of Yuma, Arizona, and just south of Interstate 8. The U.S. Bureau of Land Management established an Area of Critical Environmental Concern (ACEC) of 113,000 acres to provide for the long-term maintenance of the flora and fauna of the dunes and mountains, including the endangered Sonoran Pronghorn (*Antilocarpa americana sonoriensis).* This land is now under the management of the Department of Defense, and this study was entirely within the bounds of the Barry M. Goldwater Air Force Range.

The Mohawk Dunes are stabilized by a 7-15% perennial cover (depending on aspect) of *Pleuraphis (Hilaria) rigida* (big galleta grass), *Ephedra trifurca* (mormon tea) and *Ambrosia dumosa* (dune bursage), with *Larrea divaricata* (creosote bush) in the swales (Felger et al., 2002). From their northern terminus near Interstate 8, the dunes extend southeast for about 30 km, typically 2 to 3 km wide. They rise gradually up to 55 m above the Mohawk Valley to the southwest, the apparent direction of prevailing winds. In the lee of the wind the dunes fall sharply into the eastside valley between the dunes and the Mohawk Mountains. At their southernmost extent the dunes hook ninety degrees to run northeast through a pass in the Mohawks. The dunes fade in the broad and shallow saddle that the Border Patrol calls "Rat Gap", but then reappear for a four-mile run into the San Cristobal Valley (Figure 1).

Elevations within the ACEC range from 110 m to almost 860 m at the summit of the Mohawk Mountains. It is torrid Sonoran desert, with mean daily highs in the summer of 40 to 42 C. The mean annual rainfall at the nearest long-term station, Tacna, AZ, some ten miles to the northwest, is only 11 cm; the mean October to March rainfall is about 6 cm (Sellers, Hilld, and Sanderson-Rae 1985). From October of 2000 to the time of the survey in March of 2001, there were 7 cm of rain at Tacna.

Surveys for *B. tournefortii* were conducted from car and on foot. The species was known from the dunes (Felger et al., 2002), so the initial focus was to simply map the extent of infested dunes. The abundance of *B. tournefortii* was quantified by either "spot checks" at single localities, or by estimating density. A spot check was simply discovering a solitary cluster of one or more *B. tournefortii;* if there were no other *B. tournefortii* within view (typically a 20 meter circle), the number of individuals was recorded, along with a GPS reading.

In areas where there were more *B. tournefortii* within view of the first plants encountered, densities were estimated by recording the location of the first plants, then counting all others within a four-meter wide transect for a distance of at least 50 m or, in areas of high density, until at least 50 *B. tournefortii* were counted. In both cases the transect ended with the last sighting of *B. tournefortii*. This method of beginning and ending a transect with the presence of *B. tournefortii* exaggerates absolute densities, and makes this data suitable only for rough comparisons of densities between other dune sites in this survey, and not in comparison with the densities on the road surveys, whose transects begin and end with randomly determined points (see below). It is not a standard sampling technique, nor should it be; we seek only to explain how the distribution map was created.

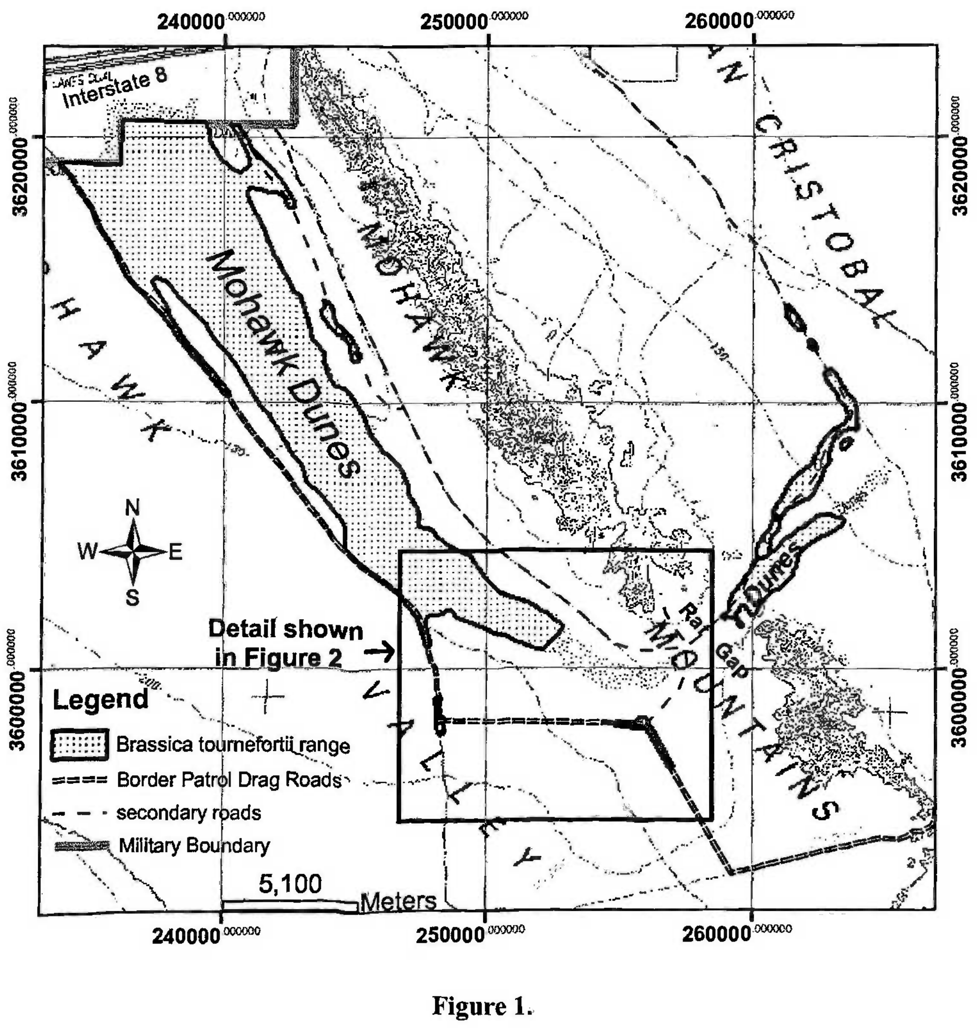

Figure 1.

Within the dune proper, this method amounted to hiking to the foot of the dune, taking note of the first plants, then continuing to hike into the dune field while counting plants within the four-meter wide corridor. To sample all aspects and slopes, there were typically three to five transects on each loop through the dunes.

The U.S. Border Patrol uses the roads to the west and south of the dune field as "drag roads" which are regularly swept by a truck towing a gang of seven to nine tires chained together to form a triangle. The resulting "tire-drag" produces a swath about ten feet across, and smooth enough to reveal footprints. *Brassica tournefortii* densities along these roads were estimated by counting plants for one hundred meters of road, both sides, extending 2 m back from the road's edge. The sampling points were determined by beginning a count with a UTM reading that ended with three zeros, e.g., 36 03 000 N, 36 04 000 N, and so forth. For roads that run due north-south or east-west, this would be precisely every kilometer.

Surveys beyond the roadside and dunes included five hikes of 3 to 6 km onto the alluvial fans of the Mohawk Mts. In addition, at the two places where the Border Patrol parked their tire-drags along the drag roads, high densities of roadside *B. tournefortii* prompted further survey several hundred meters into the surrounding desert of primarily creosote bush; when no *B. tournefortii* were seen for the last 100 m, the survey returned to the road.

All paths taken in the study were either walked or driven very slowly, with the exception of the drag road surveys, where data were taken at approximately 1 km intervals. Absence of data along secondary roads or paths indicates a lack of *B. tournefortii*, but without recording coordinates from the GPS.

All perennial species associated with *B. tournefortii* were also recorded at 48 locations, as part of an ongoing effort to map the vegetative associations and sub-associations within the range of the Sonoran Pronghorn. This information, in concert with USGS 7 ½ minute orthophoto quadrangles of the study area, allowed us to estimate the range of *B. tournefortii* in regions not directly surveyed. For example, if there were continuous sand dunes between two dune surveys that showed *B. tournefortii* present, then the dunes between were mapped as also holding *B. tournefortii*.

Results

A total of 323 spot checks and density (belt) transects were collected between 13 February and 13 March 2001. These data are available on the internet at the Southwest Exotic Plant Mapping Program of the US Geological Survey, at http://www.usgs.nau.edu/SWEPIC/swemp/maps.html. Maps were created with Arc Map 8.1. The overall distribution map, with every datum mapped, can be viewed at http://usgsbrd.srnr.arizona.edu/nbii/.

The summary map is shown in Figure 1. *Brassica tournefortii* was found between 110 m (the lower limit of the survey) and 230 m above sea level, i.e., it was absent from the stoney alluvial fans and steep mountain slopes. The southernmost Mohawk Dunes are still free of *B. tournefortii*, but the remaining dunes are infested, with the exception of the far eastern tail of the dunefield, in the San Cristobal Valley. However, judging from the spring annual bloom, there was considerably less winter rain at this one location.

Brassica tournefortii was also found in low gradient watercourses adjacent to valley floors that support creosote, dune and triangle-leaf bursage (*Ambrosia deltoidea)*, and, if sandy, big galleta grass. It was not, however, found among the saltbush *(Atriplex* spp.*)* of the San Cristobal Valley, despite having been collected with saltbush at Organ Pipe Cactus N.M. in 1978 (Felger, 1990).

Along roads, *B. tournefortii* was most common in three places: First, along the northern boundary of the Goldwater Range, near the heavily infested Interstate 8. Second, near the intersections where the Border Patrol parks the tire-drags they use to sweep the roads in their search for footprints. Third, where the road's edge led to a partial damming of rainwater that would otherwise be flowing perpendicular to the road; such damming was apparent from the unusually large creosote or triangle-leaf bursage at the road's edge.

Finally, there were three outposts of *B. tournefortiii* 10 to 25 km to the southeast. Two of these were along the main Border Patrol drag road; the furthest west population held around 100 plants under several large creosote growing next to the road berm. The second population was in a pass in the Mohawk Mountains, with another 100 plants growing along the roadside where it crossed a large arroyo, and in the arroyo itself. The third population was seven plants in the middle of a secondary road on the east side of the Mohawk Mts, only 100 m outside the north boundary of the Cabeza Prieta National Wildlife Refuge. The refuge (whose airspace is part of the Goldwater Range) has been infested with *B. tournefortii*, but to date it is mostly limited to the Pinta Sands, some twenty miles further south, near the Mexican border. As part of the Sonoran Pronghorn vegetation mapping project, Malusa hiked 180 miles during the wet spring of 2001 through a variety of habitats between the southern Mohawk and Bryan Mountains and the Growler Mountains. This area is roadless wilderness, and is upslope of the Pinta Sands and the Mohawk Dunes. No *B. tournefortii* were noted.

Discussion

The distribution of *B. tournefortii* fits well with what is known of its reproductive ecology and physiology. Felger (2000) and Minnich and Sanders (2000) note that the mustard appears to be self-compatible and hence able to spread from a single isolated seed. Thanos et al. (1991), in their study of Mediterranean plants, showed that *B. tournefortii* has the highest germination rates at temperatures of 15 to 25 C, and at seed depths of 5 mm. The rate was fairly low – only 8.4% – but a single *B. tournefortii* holds 750 to 9000 seeds (Minnich and Sanders, 2000). There was 0% germination of seeds lying on the surface, apparently due to photoinhibition. Seeds at depths greater than 5mm did germinate, but at lower frequencies.

This survey was not designed to test hypothesis of dispersal, nor correlations between a particular habitat and *B. tournefortii*. However, it should be noted that the prerequisite of its seeds being thinly buried helps explain the observed distribution of *B. tournefortii* in the Mohawk dunes, roads and arroyos, and agrees with the habitat observations of Minnich and Sanders (2000) as "most common in wind-blown sand deposits and in disturbed sites such as roadsides and abandoned fields."

Minnich and Sanders (2000) also note that "hot, dry spells frequently cause plants to reach premature flowering," and that *B. tournefortii* was "virtually absent in the (Sonoran Desert of California) after the dry (less than 25% of normal) winters of 1995-96 and 1996-97." Throughout the Mohawk Dunes study area it appeared that *B. tournefortii* prefers places with the most moisture, such as arroyos. Roadsides are not only disturbed but also benefit from enhanced runnoff. Within the dunefields, *B. tournefortii* was most often observed at the foot of slopes facing northeast, north, and northwest, where up to 500 plants could be found within 50 m. South-facing slopes and the swales between dune crests were the least favorable. Dune crests were intermediate.

The southernmost stretch of the Mohawk Dunes (Figure 2) are still free of *B. tournefortii* probably because they are isolated from the main dunes by a swale of creosote bush that is apparently less desirable habitat. This barrier will likely be breached, as the swale is less than 100 m wide, and *B. tournefortii* was, elsewhere, occasionally found growing in full sun on creosote flats. With a mean seed weight of a mere 1.3 mg (Thanos et al. 1991), even sheet flooding across creosote flats is apparently sufficient to transport *B. tournefortii*. Circumstantial evidence can be found in the distribution of *B. tournefortii* on the downslope side of colonized roads. For example, along the main tire-drag road south of the dunefield (Figure 2), *B. tournefortii* could be found up to 60 meters downslope (north) of the road, among creosote. Upslope, to the south, none were found.

Similarly, the northernmost *B. tournefortii* in the valley between the Mohawk Dunes and the Mohawk Mts. (Figure 1) were likely derived from the thriving Interstate 8 population, and transported down slope, south, towards the Mohawk Playa at the foot of the dunes. Further south from this playa it is uphill – and there are no more *B. tournefortii* in the valley.

The further spread of *B. tournefortii* is likely hastened by a combination of disturbance and moisture. Minnich and Sanders (2000) noted that "During rains, a sticky gel forms over the seed case that permits seeds to disperse long distance by adhering to animals. The rapid spread of *Brassica tournefortii* through the Sonoran Desert, with first occurances along roadsides, may be related to its ability to adhere to automobiles during rare periods of wet weather." Along the drag roads near the Mohawk Dunes it is not even necessary to adhere to an automobile, because the Border Patrol tire drags inadvertantly scoops up plants, scatters the seeds, and promptly buries them.

The arroyos are avenues of dispersal also, but perhaps slower than might be expected, because the watercourses in this arid stretch are discontinuous. Small arroyos are tributaries to larger arroyos, but these in turn do not reach to the center of the valley. Instead, they fan out in distributaries that ultimately fade among the creosote and bursage. Such a pattern is seen in the arroyos draining into the San Cristobal Valley from Rat Gap, fanning out from the presumed point of original colonization where the road crosses the upper watershed (Figure 1).

It is likely that the road through Rat Gap introduced *B. tournefortii* to this arroyo system (and subsequently the eastern dunes of the San Cristobal Valley) in recent years. On the 1997 aerial photos of the Goldwater Range this road is scarcely visible. In the intervening four years it has been graded so even a car can pass. Judging from the vehicle tracks that were observed leading to abandoned water jugs, or paralleling the footprints of walkers, the Border Patrol often leaves the road in their trucks and in the process drive through patches of *B. tournefortii*, further spreading the seed.

The ecological effects of *B. tournefortii* colonization remain to be documented. In a land with so much open space, it's not hard to imagine that it's simply moving into unoccupied terrain. But some species, like the desert iguana, favor open habitat, possibly because predators can't hide in thin air. For example, the numbers of desert iguanas seen along road transects in Avra Valley near Tucson, AZ., declined substantially between June 1977 and June 1978, following a very wet winter that produced a bumper crop of the invasive grass, red brome (*Bromus rubens*). (C. Schwalbe, pers. comm.).

The pervasive concern among botanists is simply the shading of native species, particularly on the dune fields. The sand hills are unique in that 74% of their plant species are cool season annuals (Felger et al. 2002). *B. tournefortii*, with its preferred germination temperature of 15 to 25 C, can get the jump on most of the native species if there is a late season hurricane in October or November. There is, naturally,

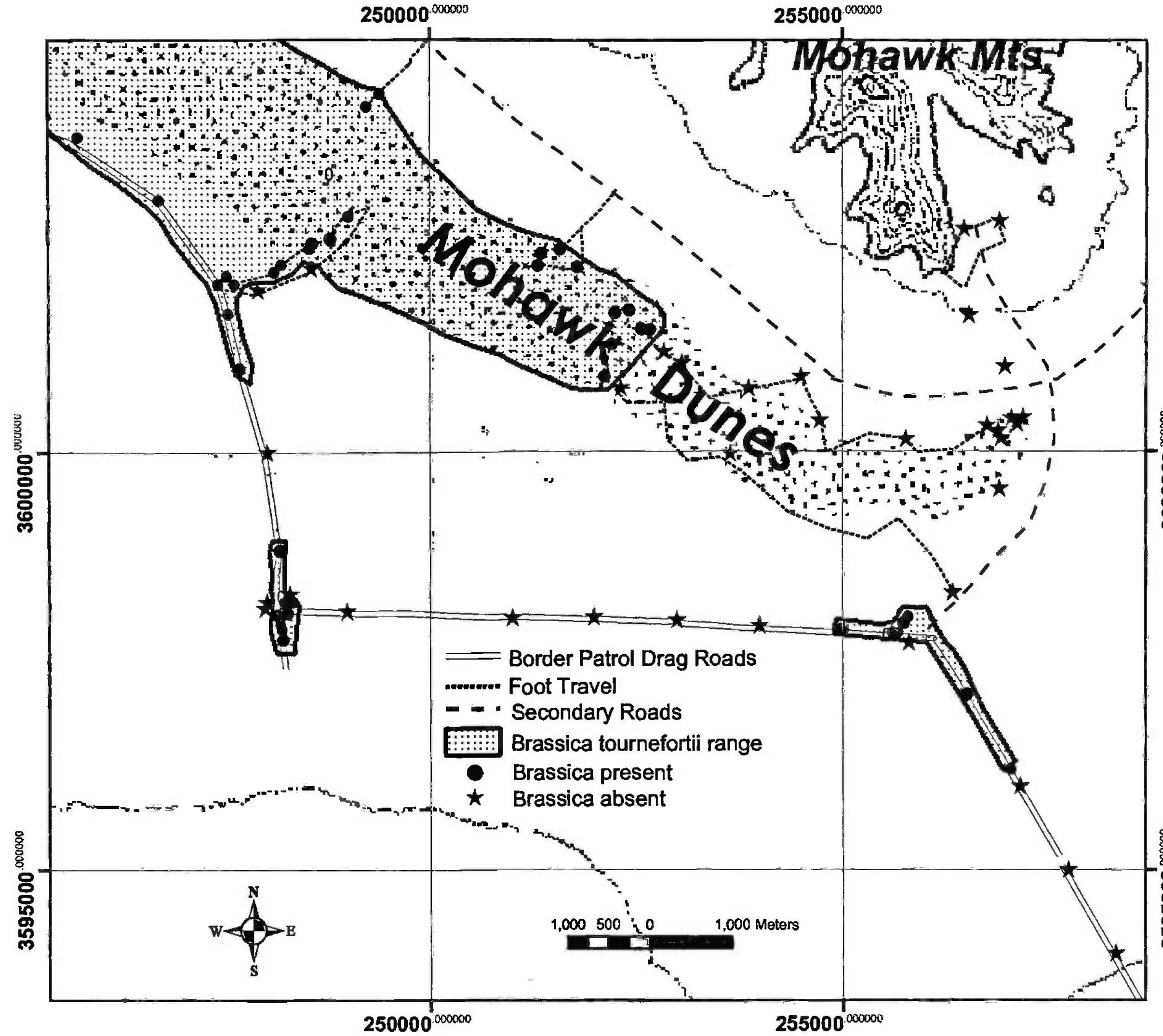

Figure 2.

nothing that can be done about this situation, except study the section of dunes that remain uncolonized. The uncolonized area is large enough to consider saving, via monitoring, and eradication when needed.

Roads facilitate further colonization of the Goldwater. Roads provide habitat by altering drainage patterns, provide a vector in the vehicles upon the roads, and in the case of the Border Patrol tire drags, provide the preferred germination conditions by burying the seeds of *B. tournefortii*. Studies of roadsides in the Nevada Test Site showed that exotic species of *Bromus, Erodium* (filaree), *Salsola* (tumbleweed), and *Sisymbrium* (a mustard) dominated all roads except one that had been closed to traffic for an undetermined number of years (Hunter 1990). Closed roads can recover.

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FIGURE CAPTION

FIGURE 1. The distribution of *Brassica tournefortii* in and around the Mohawk Dunes, Arizona, is shown by heavy outlines. Interstate 8 runs through upper left. Base map is Ajo 1:250,000. UTM coordinates are NAD 1927 Datum.

FIGURE 2. Detail of Figure 1, showing the uncolonized section of the Mohawk Dunes, and the Border Patrol Drag Roads. Data points are simplified to show only the presence/absence of *Brassica tournefortii.* Base map is Ajo 1:250,000. UTM coordinates are NAD 1927 Datum.

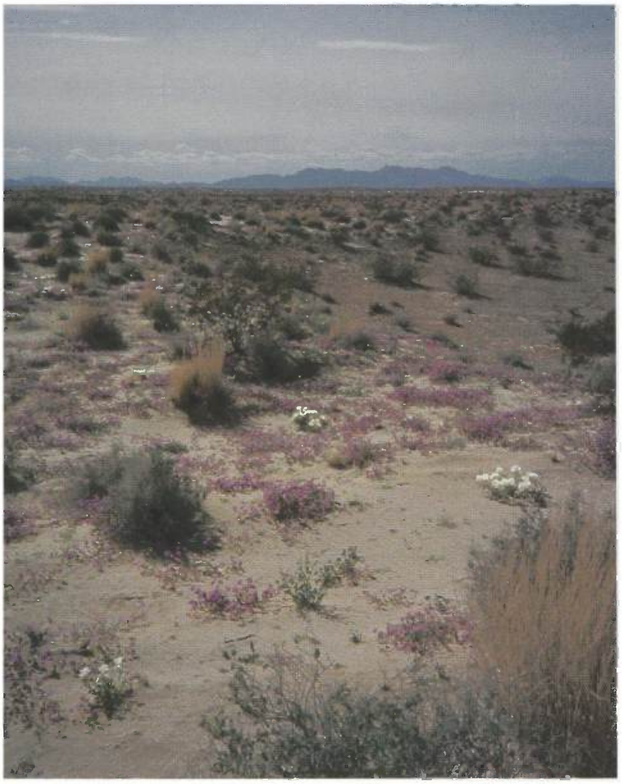

Figure 3. Mohawk Dunes where no *Brassica* is growing.

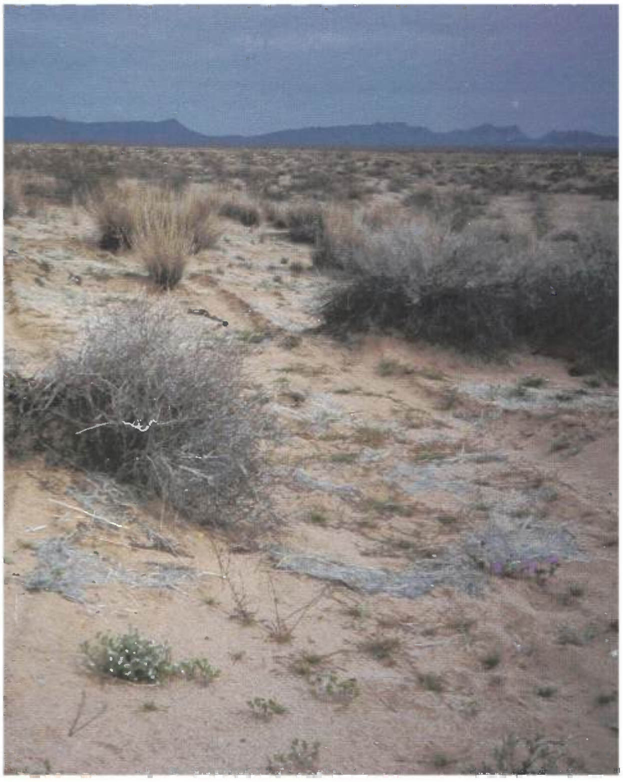

Figure 4. *Brassica* in the dune field.

Figure 5. *Brassica* growing outside the dunefield in area affected by roads.

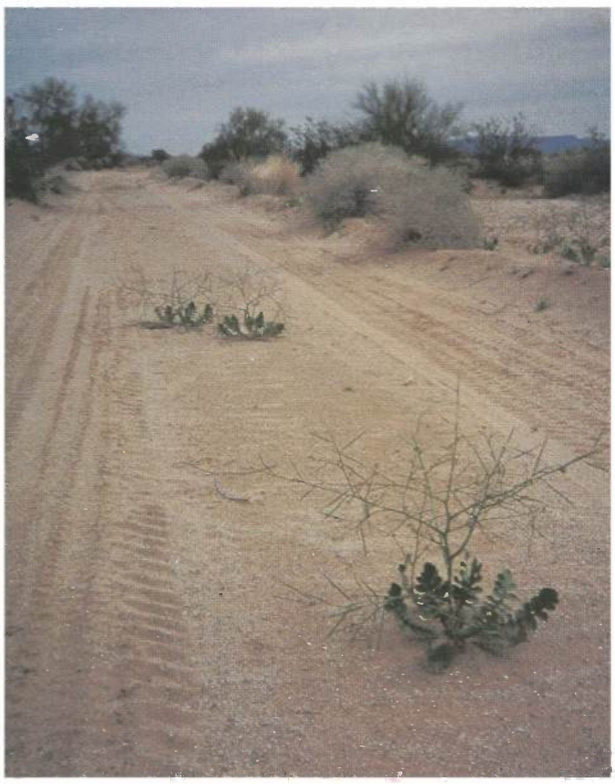

Figure 6. Fresh tire tracks through the Mohawk Dunes.