DRAFT

Geological and Ecological Diversity in the Proposed Ironwood Preserve:

Assessing Rock-Soil-Plant-Wildlife Relations in the Silverbell, Ragged Top, Waterman and Roskruge Ranges of Pima County, Arizona

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Executive Summary

- The Pima County area encompassing the Silverbell, Ragged Top, Waterman, and Roskruge mountains is an outstanding representation of the Arizona Upland subregion of the Sonoran Desert. This is the area is referred to as the *study area* for the remainder of this document.

- Its geology is unusually diverse. The four main mountain ranges are distinct from one another and contain a diverse array of bedrock types, which weather into a much greater number of soils and landforms of varying ages.

- The study area has recently been identified by The Nature Conservancy as one of the top 40 sites in the Sonoran Desert Ecoregion in terms of the number of conservation target species it shelters, and among the top 20 in Arizona's portion of that ecoregion.

- The Waterman Mountain range along with the Vekol Mountains on the Tohono O'odham Reservation are the only massive limestone mountains within Arizona Upland. The Watermans support 29 plant species, including the federally Endangered Nichol's turk's head cactus, that do not occur anywhere in the rest of the area. This cactus is known from only three localities in Arizona and a fourth in Sonora.

- The geologic and topographic diversity contributes to the area's high biological diversity. For example, there are 484 taxa (species and subspecies) of plants in 72 families within the study area. Although Saguaro National Park and Organ Pipe Cactus National Monument have substantially larger floras, the study area is considerably richer than typical desert ranges such as the South Mountains (274 taxa) or the Sierra Estrella (330 taxa).

- The Silverbells have only half as many exotic plants as the two major preserves in Pima County, reflecting a lower degree of human disturbance.

- The mountain ranges in the study area shelter several relict plant populations, especially Arizona rosewood and shrub live oak. Some individuals of rosewood and oak appear to be ancient remnants of more widespread woodlands from the last Ice Age.

- The Silverbell Mountains support the highest densities of desert ironwood trees recorded to date in the Sonoran Desert. The ironwoods here harbor more associated plant species than anywhere else studied.

- The study area could form the cornerstone for protecting the range of ancient ironwood and cactus habitats, which vary from upland habitats, across bajadas to floodplains on valley floors.

- A total of 177 vertebrate species and at least 821 invertebrate species have been recorded in the study area. These numbers include several species federally listed as Threatened and Endangered, including historic and potential habitat for the Cactus Ferruginous Pygmy Owl. The desert bighorn sheep in the Silverbells may represent the last viable population indigenous to the Tucson basin.

- Other species of concern harbored in the study area include California leaf-nosed bat, Mexican long-tongued bat, lesser long-nosed bat, western red bat, Merriam's mesquite mouse, Rufous-winged Sparrow, Tucson shovel-nosed snake, ground snake, Pima pineapple cactus, Nichol's turk's head cactus, and three talus snails.

- The study area provides habitats complementary to those in Pima County already protected by Saguaro National Park and Organ Pipe Cactus National Monument. The enhanced protection of these ranges would help build a regional network of habitats functional as a corridor for migratory wildlife such as bat, hummingbird and dove pollinators.

- The study area has a long history of research in desert ecosystems. The ample baseline data collected here over several decades make the area a prime candidate for future studies of environmental change. While more botanical studies have been done on Tumamoc Hill, more studies of functional processes of desert ecosystems have been done in the Silverbells. Tumamoc Hill is now significantly impacted by urban encroachment and is no longer a pristine environment. The mountain ranges in the study area have considerably more intact vegetation, and are further from urban encroachment and exotic weed invasion.

INTRODUCTION

Less than an hour from downtown Tucson, four adjacent ranges define the western edge of the Avra and Altar valleys: the Silverbells, Ragged Top, Watermans, and Roskruges. It is easy to do a slow loop around the area on Silverbell and Avra Valley roads without seeing another soul all day. Walking through the Arizona Upland vegetation there, you can see why this subregion of the Sonoran Desert is also called the ancient legume and cactus forest. The trees are so tall and dense in places that they conceal your view of Ragged Top looming behind them, and you can't walk more than a few paces without having to veer around a tree or cactus. At first sight it's difficult to understand why this is called desert. But the drought-adapted species define it. Even though desert ironwood has dark green, lush foliage much of the year, this tree is almost exclusively a Sonoran Desert species. The same is true of the distribution of saguaros, foothill palo verdes, fishhook barrel cacti, and most of the hundreds of other plants growing here. These rugged ranges also provide natural refuges for a variety of wildlife, including desert bighorn and migratory pollinators. In addition to the biological resources, the area has abundant rock art sites and other archeological sites, with additional cultural resources continuing to be discovered. These ranges comprise an excellent representation of the Arizona Upland subregion of the Sonoran Desert for the reasons described in the rest of this report.

GEOGRAPHIC CONTEXT

Overview

The study area exhibits typical basin and range topography with valley floors and alluvial slopes lying between 1800 and 2600 feet elevation. Four main mountain ranges rise above this base: the Silverbell, Waterman, Ragged Top, and Roskruge. Their summits vary from 3721 feet in the Roskruge Mountains to 4261 feet in the Silverbells. In addition there are several smaller ranges and isolated hills nearby. (Figure 1)

The diverse and unusual geology undoubtedly influences the level of biological richness. Very complex bedrock geology may be simplified for the purpose of this report into a few categories: limestone (with some included shale and quartzite), red-colored sediments, light-colored volcanics, dark-colored volcanics, and granite. These rocks weather into a diversity of slopes and soil types, which vary greatly in age and stability, nutrient content, water infiltration rate, and moisture-holding capacity. There is no doubt that these soil factors contribute to the area's biodiversity.

The Waterman Mountain range is comprised of a variety of Paleozoic sedimentary rocks. The Waterman and Vekol mountains are the largest limestone massifs within the Arizona Upland Subregion. Many plants preferentially grow on these exposed limestones and some are restricted to them (see Flora section).

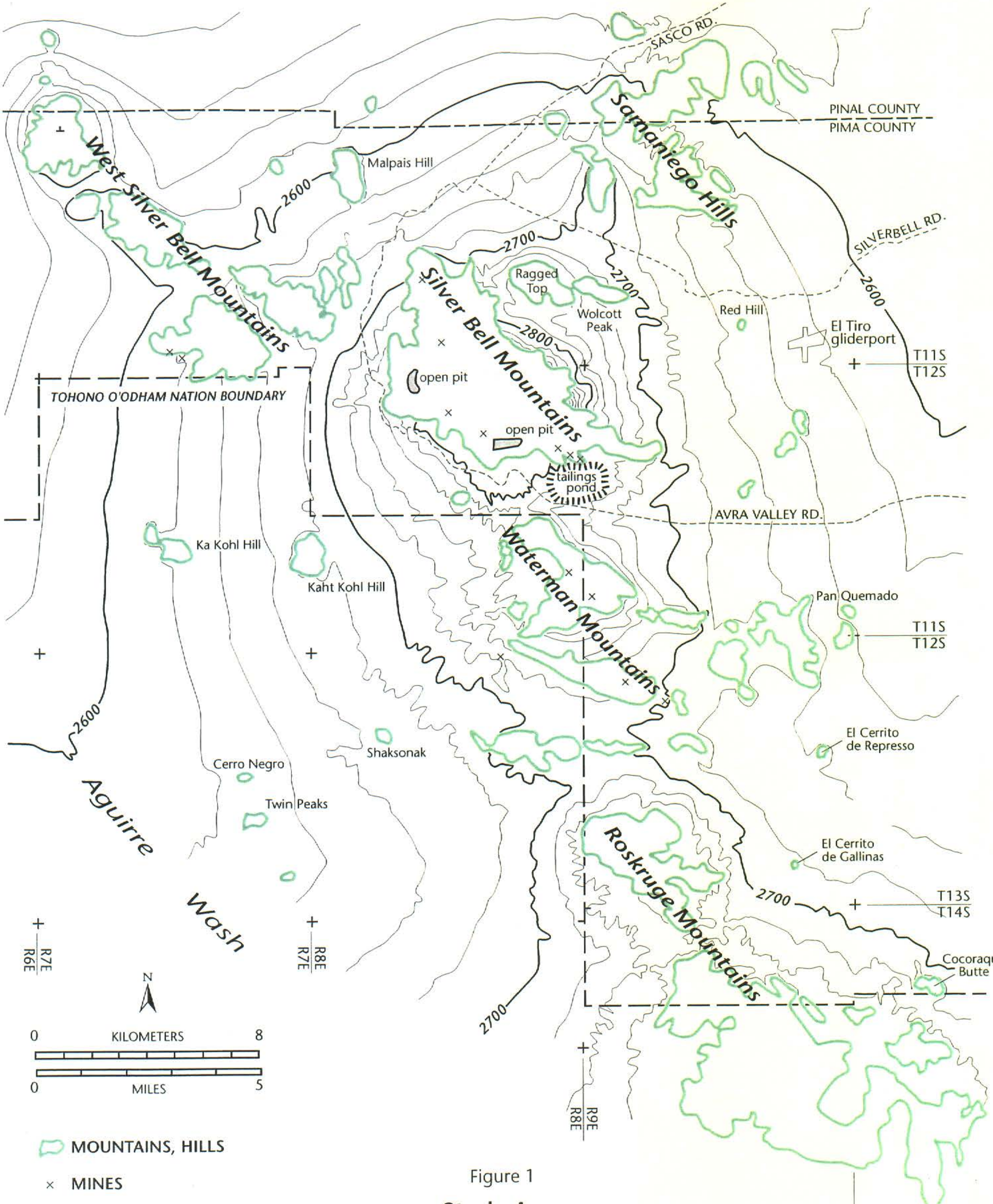


Figure 1

Study Area
SILVERBELL, WATERMAN AND ROSKRUGE MOUNTAINS
Pima County, Arizona

The region is also unusual in having extensive areas of highly mineralized soils, rich in copper, molybdenum, arsenic, and a dozen other related elements (Jim Briscoe, unpublished data) derived from the copper and base metal mineralization found scattered throughout this region. These minerals undoubtedly influence the biota, but little research has been done to describe and explain these relations.

Discussion

Topography

Topographically, the study area is similar to other nearby desert mountain ranges of the region, similar in elevation and extent with the nearby Comobabi and Tucson Mountains. All contain bajada slopes of similar areal extent, surrounding bedrock mountains with comparable heights.

The study area encompasses portions of seven USGS 7.5 minute quadrangles. Elevations above sea level (asl) span between lows near 2000 feet along Avra Valley Road, to a maximum of 4261 feet at Silverbell Peak in the Silverbell Mountains, with total relief of 2250 feet. All mountainous areas are surrounded by gently sloping bajada surfaces (the gentle fan-shaped slopes adjacent to rugged mountain fronts), which maintain a few percent valleyward slope (few hundred feet per mile) where they join the edge of floodplains of the Santa Cruz River or Brawley Wash to the east and Aguirre Wash to the west. Maximum absolute elevations of bajadas range from about 1800 feet to about 2600 feet. Elevations of peak tops above the upper end of the bajadas range from about 300 to 650 feet in the Roskruge Mountains, Pan Quemado Hills and Samaniego Hills, to 1420 feet in the Waterman Mountains, and 1661 feet at Silverbell Peak. The general topographic setting is depicted in Appendix I, which shows the characteristic elevational amplitude and slope of the bajada surfaces, and the location and geologic composition of bedrock hills and mountains.

Surficial geology studies

Some surficial geology studies include portions of the study area. Such maps include those of Ferguson et al. (1999a & b), Field and Pearthree (1993), and Sawyer (1996). These maps differentiate between older alluvial units capped with mature soils with thick clay and caliche horizons, and younger unconsolidated and permeable alluvial surfaces covered with thinner soils. At least a dozen kinds of surfaces are shown on some of the maps, ranging in age from about three million years to late Holocene, a few thousands years. In our reconnaissance along the north side of the Silverbell Mountains, two soils with varying surface colors (reddish and green-gray), appear to support plant communities with somewhat different species composition, particularly regarding creosote bush and bursage. Here the surface colors clearly derive from very different kinds of parent bedrock. Additionally, most alluvial fans on the east side of the Silverbell Mountains carry material from more than one bedrock source, and record a complex depositional history. McAuliffe (1999) has detailed the complexities encountered in regional bajada soils that result from complex Quaternary stream actions.

Arizona Geological Survey (Tucson) personnel under the direction of Phil Pearthree are mapping the surficial geology on a comprehensive scale in the Santa Cruz, Altar, and Avra Valleys. They are currently mapping the surficial geology of two 7.5 minute quadrangles (Waterman Peak; West of Avra), scheduled for publication by October 2000.

The geology-geomorphic map (Appendix I) produced for this report displays a simplified series of four bajada soil-surface units in the study area, derived from a color-enhanced LANDSAT image without significant field checking. The units (Q1, Q2, Q3, and QT) are separated based upon variations in surface color (an age-related phenomenon) and degree of dissection of the surface by modern stream channels. More heavily dissected surfaces are typically darker-colored, and usually older. The oldest elevated terrace remnants (QT unit) are likely early Pleistocene age (McAuliffe 1999), while many Q1 surfaces are Holocene-age (less than 10,000 years old).

Both plant species diversity and plant composition appear to be influenced by alluvial characteristics. McAuliffe (1999) describes how age of surface and parent rock type profoundly affect soil properties, resulting in highly variable rainfall percolation, root penetration, and size and diversity of nurse plant cover. The degree of dissection of surfaces by streams (rills, arroyos) lessens infiltration across broad areas while funneling runoff into channels. The largest trees are typically found along the channels where the runoff is magnified and water infiltration is greater. In the eastern Waterman Mountains, some youthful alluvial deposits consist of very permeable rederived wind-blown silt and sand.

Another class of bajada surface called a 'stripped' pediment is present in areas containing trimmed-off bedrock masses mantled beneath shallow soils. Though lacking significant alluvial cover, this kind of surface develops most rapidly on granite when it becomes weathered to coarse sandy alluvium, and so may support moisture conditions and plant communities comparable to areas covered by alluvial soils. Two areas where pedimented granite bedrock is exposed can be seen in the northern Silverbell and south of the Watermans, where they support a diverse plant communities.

Geological formations present

Dozens of bedrock types are recognized in the study area, predominately of igneous and sedimentary origin. For convenience, these may be grouped into eight generalized map units, including: limestone-shale, fine-grained sedimentary rocks of two varieties, light-colored (rhyolitic) volcanic rocks, dark-colored (basaltic) volcanic rocks, and granite. Appendix I indicates the distribution of these rock types in the study area. Limestone and rhyolitic bedrocks generally weather to rugged cliffs which support uncommon or exotic plant species especially when northward-facing. The Waterman Mountains are one of the two largest exposed massifs of limestone in the upper Sonoran Desert region. Other smaller outcrops and knobs of limestone are found in the Silverbell and Tucson ranges, but all lack the areal and vertical extent of the Waterman and Vekol outcrops.

In addition to contributing rock parental material to alluvial or bajada surfaces which occur downslope, bedrock types influence local plant community composition in mountains in several ways. These range from chemical control of soil acidity, to providing cooler shadow zones on steep northern slopes. The distributions of saguaro, creosote bush, spike moss, ocotillo, and Nichol's turk's head cactus in the Waterman Mountains suggest considerable bedrock influence. The abundance of saguaros growing on Cambrian-age quartzites and slates in several places is especially striking, while much less dense populations are found on limestone outcrops (McAuliffe 1999). (Figure 2)

Distribution of the most dense stands of ironwood trees may be influenced by slope aspect, as they seem to prefer upper parts of north- and west-facing bajadas, irrespective of nearby bedrock geology or soil type. Ocotillo grows most commonly on shales. Spike moss is the dominant ground cover on Andrada and Scherrer quartzites and less so on Precambrian granite, while uncommon to absent on limestones and shales. Nichol's turk's head cactus is largely restricted to massive limestone outcrops of the Horquilla Formation, but also occurs sporadically on the Andrada and Scherrer formations and on the older relict caliche soils on steep alluvial fans around the mountains (Schmalzel and Francisco, in preparation). There may be a unique correlation between the occurrence of false grama grass and massive quartzite bluffs representing an ancient sedimentary series called the Apache Group, which outcrop only in the quartzite hills east of Ragged Top (see page 16).

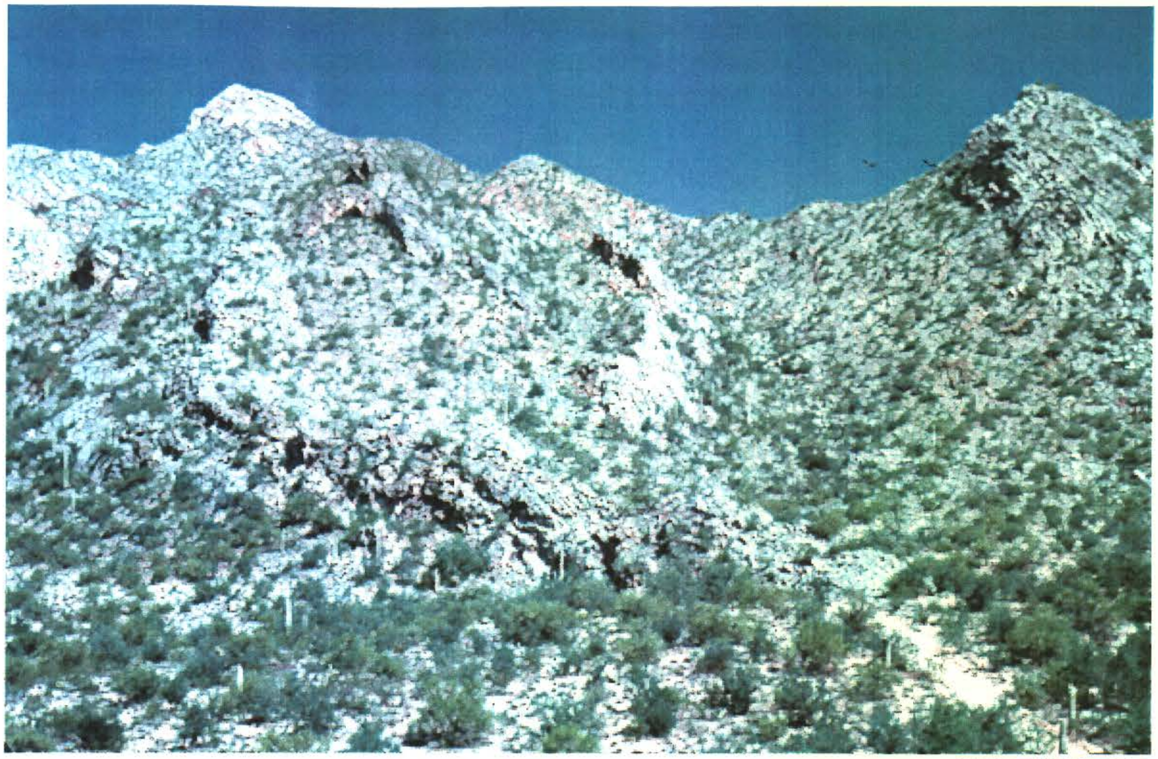
In the Waterman Mountains, McAuliffe (1999) distinguished creosote bush vegetation on upper bajada surfaces on strong limestone-derived soils from that on non-limestone soils which contain argillic horizons, which have more saguaro and triangle-leaf bursage. The spotty distribution of creosote bush on bajada slopes in the western Silverbells may relate to the mineralized soils derived from an upslope copper ore body.

Some bajada soils in the study area exhibit special soil chemistry which is influenced by significant buried metallic orebodies. Elemental analyses of soil, bedrock, and plant matter (Briscoe, J. A., pers. comm.), suggest the presence of several porphyry ore bodies containing very significant copper, lead, zinc, silver, gold, molybdenum, selenium, arsenic, and tellurium. Additionally, two partially exhausted ore bodies in the Waterman Mountains (Silver Hill and Indiana-Arizona) represent skarn-type replacement ore bodies in limestone and shale, possibly related to the Silverbell mines (Nowlan and others 1989). Ultimately, buried ore bodies contribute various trace elements to soils, along with special clays and other minerals which are otherwise not found in local soils.

FLORA

Overview

The known flora of the four mountain ranges and intervening valleys currently totals 484 taxa (species, subspecies, varieties) in 72 families. This compares favorably with the 646 taxa in 72 families in the Tucson Mountains (Saguaro National Park West and Tucson Mountains County Park combined), which are somewhat taller (4361 feet) and have been more intensively surveyed. It also compares well with the larger Organ Pipe Cactus



Thomas R. Van Devender

Figure 2. Saguaros in limestone-quartzite in the Waterman Mountains.

The view northwest towards Waterman Peak in the Waterman Mountains. Rugged limestone-quartzite cliffs support a diverse Arizona Upland vegetation, while the vegetation below is dominated by ironwwood and mesquite. A patch of darker rock on the skyline to the right peak supports a dense stand of saguaros.

National Monument which has 522 taxa in 86 families in 13,898 hectares. (Detailed lists are in Appendix II)

The floras of the four mountain ranges reflect their geographic locations relative to the other Pima County preserves. The Tucson Mountains are at the eastern edge of Arizona Upland, while Organ Pipe National Monument is at the western edge. Organ Pipe also contains extensive areas of Lower Colorado River Valley vegetation, and because of its warmer winters compared to the other two protected areas, it has several northern range records for southern, tropical species. Sixty taxa (12%) of the study area flora are not found in the Tucson Mountains, and 151 taxa (31%) are not found in Organ Pipe National Monument. Eight per cent of the Silverbell area flora (41 taxa) are not found in either of the other two reserves (Figure 3).

Limestone has a major influence on plant growth, and it is rare in Arizona Upland habitat. This is why the Waterman Mountains have more than 25 plant species that do not occur in the rest of the study area, or in the Tucson Mountains or Organ Pipe Cactus National Monument, which lack significant limestone.

The number of exotic species is an indicator of disturbance in an ecosystem. The Silverbell area has fewer exotics (41 species, 8% of the flora) than the Tucson Mountains (86 taxa, 13% of the flora) (Figure 4). This most likely reflects the proximity of the Tucson Mountains to a major city and the greater rate of exotic introductions. The Silverbells compare favorably with Organ Pipe, which has 31 exotics (6% of the flora).

Discussion

The four ranges in the study area are among more than 100 that occur within the boundaries of the Sonoran and Mohave deserts. Three of them (not the Roskruges) are among 26 that rise high enough to support nondesert vegetation on their summits (Brown 1978). In the study area, relicts from the wetter Pleistocene climates are restricted to cooler north-facing slopes that receive concentrated runoff from cliffs or steep rocky slopes (Appendix IV). In the Silverbells, they occur near the summit among rocks. Some of the rosewoods and shrub live oaks are evidently root-sprouts from older mother plants that have died back at the center. It is possible that some of these clonal individuals established at the end of the Ice Age and have clung to life in these sheltered microclimates for thousands of years (Bob Schmalzel, pers. comm.).

There are numerous noteworthy plant species with respect to range limits, rarity, and relicts from previous climatic regimes.

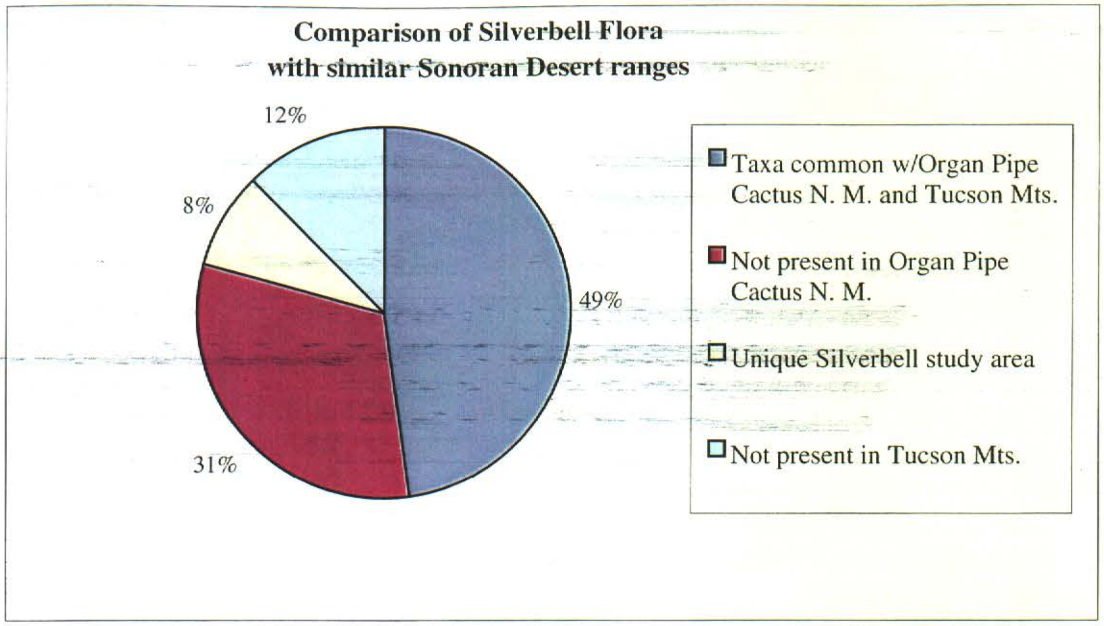


Figure 3. Comparison of silverbell area flora with similar Sonoran Desert ranges.

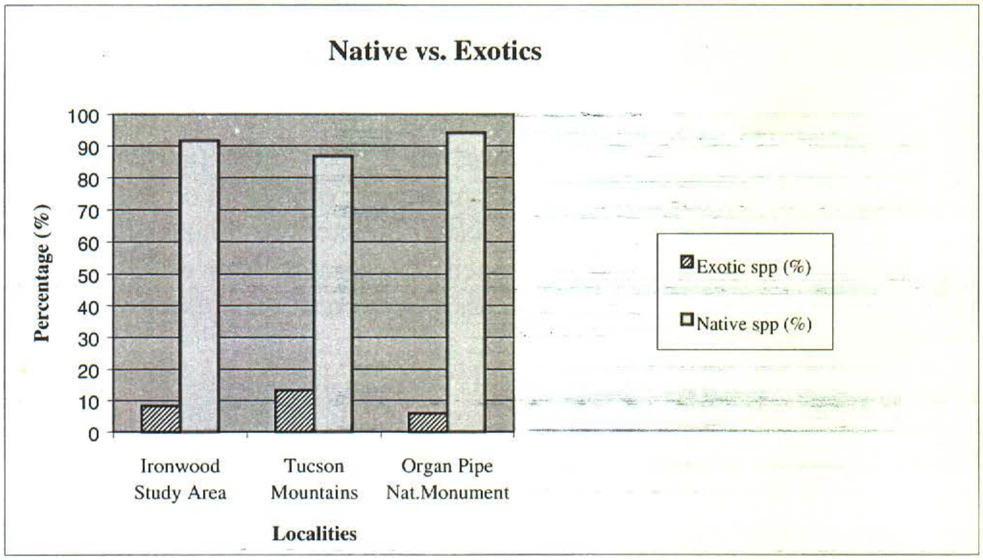


Figure 4. Native vs. exotic species

Range notes:

Abutilon mollicomum (pintapán cimarrón) - This mallow is unusual for Arizona Upland ranges, being subtropical, and found to the east and south in wet canyons. [not in Tucson Mountains or Organ Pipe National Monument]

Agave deserti (desert agave) – The Waterman and Silverbell mountains are the easternmost edge of the range of this widespread rosette succulent. The nearest population in the Vekol Mountains is around 60 km ESE. [not in Tucson Mountains]

Astrolepis (Notholaena) jonesii (Jone's cloak fern) – An uncommon fern on rock faces in Waterman population seems to be the southeast range limit. Nearest population 110 km NNE at Superior, Arizona. [not in Tucson Mountains or Organ Pipe National Monument]

Croton sonorae (vara prieta) – A desert scrub at or near the northeastern edge of its range; occurring from the Roskruge Mountains up to Ragged Top. [not in Tucson Mountains]

Echinocereus engelmannii var. *acicularis* (strawberry hedgehog) - The southeastern edge of this widespread desert hedgehog cactus. [not in Tucson Mountains or Organ Pipe National Monument]

Echinocereus nicholii (golden hedgehog) – The Silverbell Mountains are near the northern limit of the range of this golden-spined hedgehog. This is also the densest population known to the authors.

Galium microphyllum (bedstraw) - A streamside herb uncommon on dry, desert peaks, like Ragged Top. [not in Tucson Mountains.]

Geraea canescens (desert sunflower) – A low desert spring annual at or near the eastern edge of its range. [not in Tucson Mountains]

Graptopetalum rusbyi - An uncommon succulent on desert peaks. [not in Tucson Mountains]

Matelea arizonica (milkweed vine) - An uncommon milkweed vine known in Arizona only from Sycamore Canyon, and the Baboquivari, Rincon, and Santa Catalina Mountains. It is odd to find this moist canyon-loving plant on the north side of Ragged Top. [not in Tucson Mountains or Organ Pipe National Monument]

Mentzelia involucrata (sand blazingstar) – A spring annual with a pale "ghost flower" at the eastern edge of its range in the Watermans and Ragged Top. [not in Tucson Mountains]

Monardella arizonica (bee balm) – an aromatic subscrub on rock faces that is scattered on dry, desert mountains. Watermans and Ragged Top marks the eastern-most edge of range; around 60 km ENE of the Quijotoa Mountains. [not in Tucson Mountains]

Opuntia macrocentra (longspine prickly pear) - A grassland and Chihuahuan Desert prickly pear that is uncommon in Arizona Upland Sonoran Desertscrub. This species is at the western-most edge of its range from the Roskruge Mountains, Watermans, Silverbells, and Ragged Top. [not in Tucson Mountains or Organ Pipe National Monument].

Panicum hallii (Hall's panic grass) - A tufted perennial grass found commonly in desert on higher elevations in desert grassland and Chihuahuan desertscrub further east than the Waterman population on limestone in the desert. [not in Tucson Mountains or Organ Pipe National Monument].

Viguiera deltoidea var. *parishii* (golden eye) – A widespread desert scrub that is rare on Ragged Top; at or near the eastern edge of its range. [not in Tucson Mountains]

<u>Unusual Plants or Those With Special Governmental Status:</u>

Abutilon parishii (Pima Indian mallow) - An uncommon herbaceous perennial mallow that was a candidate for federal listing as an endangered species. Its range is wide, but it is rarely common wherever it occurs. It is rare on Ragged Top [not in Organ Pipe National Monument].

Bursera microphylla (elephant tree) – An uncommon shrub or small tree in desert ranges in Arizona; Waterman population is easternmost in Arizona. Plants are scattered on southern exposures on massive bedrock of Concha and Escabrosa limestones in the Watermans. This population shows morphological differences from others, indicating hybridization or speciation; its taxonomic status is under investigation. Listed on the Nature Conservancy's Conservation Priority Report. [not in Tucson Mountains.]

Cathestecum brevifolium (false grama, zacate borreguero) – The only locality for this dwarf tuffed perennial grass in the United States is in the hills of Apache Group quartzite east of Ragged Top, where it occurs in bands across the middle of the south-facing slopes of the four highest hills. This is the only major locality of this rock group in the study area. The nearest known populations are 225 km SSW at Pitiquito, and 225 km SSE at Cerro Cinta de Plata, both in Sonora, Mexico.

Echinocactus horizonthalonius var. *nicholii* (Nichol's turk's head cactus) – A cactus that was federally listed as endangered. The Waterman population is the easternmost of the 3 in Arizona (Koht Kohl & Vekol Mountains) and one in Sonora, Mexico (Sierra del Viejo). Threatened by copper and limestone mining and illegal collecting. Listed on the Nature Conservancy's Conservation Priority Report. [not in Tucson Mountains or Organ Pipe National Monument]

Pisonia capitata (garabato) - Ragged Top is the only site for this tropical woody vine in the United States. The five female plants of this species on Ragged Top mark a range extension of 460 km NNW of the nearest known population at Soyopa, Sonora, Mexico.

Waltheria indica - An uncommon tropical herb under study by the BLM (John Anderson). It is rare on Ragged Top. [not in Tucson Mountains or Organ Pipe National Monument]

<u>Relicts from former chapparal and woodland communities.</u>

Bouteloua curtipendula (Sideoats grama) – A common desert grassland grass, occurs on most of the area's ranges

Bouteloua eriopoda (Black grama) - A widespread perennial grass in the southwestern United States occurs in the Watermans only [not in Organ Pipe National Monument]

Brickellia californica (pachaba) – this scrubby composite, a typical plant of mountain woodland is scattered at cliff bases on Ragged Top.

Eragrostis intermedia (plains lovegrass) - is widespread in desert grassland and interior chaparral. Ragged Top only.

Ipomopsis multiflora - Subshrub typically found from 4000'-9000' elevation to the east and north of its Ragged Top locale (<3600'). the nearest population is probably the Santa Catalina Mountains. [not in Tucson Mountains or Organ Pipe National Monument]

Leptochloa dubia (green sprangletop) - A widespread perennial grass found in the Silverbells and Ragged Top.

Quercus turbinella (shrub live oak) – The rare plants (7) are Pleistocene relicts on Ragged Top.

Vauquelinia californica (Arizona rosewood) - A shrub typical of the lower oak woodland or interior chaparral, shrub live oak is a dominant in interior chaparral from new Mexico to Central Arizona and California. Rare on the Silverbells and Watermans; locally common on northerly cliffs and canyons of Ragged Top.

Yucca arizonica (Arizona yucca) – This stalked yucca is rare in Watermans and Ragged Top; abundant at higher elevations of the Silverbells.

Special botanical features in the Waterman and Roskruge Mountains.
In particular, the limestone Waterman Mountains have long been known as a locality for the Nichol's turk's head cactus, a Sonoran variety of a Chihuahuan Desert cactus that was listed as a federally Endangered Species in 1979. Senior Research Scientist Tom Van Devender was an author on the 1986 recovery plan for the species (May et al. 1986). Bob Schmalzel, a Research Associate with the Museum, is continuing to study the distribution and demography of this plant. Wright (1970) studied the creosote bush in the Avra Valley. He was the first to recognize the asexual clonal rings in sandy soils. Vasek (1980) concluded that similar rings in southern California were many thousands of years old.

Fossil plants in ancient packrat middens document that the modern Sonoran desertscrub with saguaro, foothills paloverde, and ironwood did not form until about 4000 years ago. A single seed of Nichol's turk's head cactus in a packrat midden dated 22,450 yr B.P. indicates that it is an old relictual population. The relatively isolated elephant tree only arrived in the Waterman's about 6000 years ago.

Sonya Norman discovered an isolated organpipe cactus in the Roskruge Mountains. In the Watermans, Schmalzel discovered relictual Arizona rosewood, and Van Devender discovered turpentine bush.

VEGETATION

Overview

The vegetation of these four ranges are a classic representation of the Arizona Upland subregion of the Sonoran Desert. This subregion is defined by rolling to steep, mostly rocky terrain with legume trees and saguaros as the visually dominant vegetation. The dominant trees are foothill palo verde and desert ironwood, with blue palo verdes occurring mostly in the larger drainages. There is a rich understory layer of shrubs and cacti, and many species of annuals that appear in abundance only in wetter years. (Appendix V)

The lower bajadas and valley floors are dominated by creosote bush and other shrubs; saguaros are sparse, and trees are restricted to drainages. This vegetation represents the eastern edge of the Lower Colorado River Valley subregion, which occupies most of southwestern Arizona and adjacent California, Sonora, and Baja California. The typically finer-textured soils of the lower bajadas and valleys are more moisture-retentive than coarser upland soils. But the Lower Colorado River Valley subregion is hotter and drier than Arizona Upland, which explains much of the difference in plant distributions between the two subregions.

The densest stands of ironwoods and palo verdes occur where the soil is derived from Precambrian Oracle granite. This granite is characterized by large crystal size and weathers into a coarse, very porous soil that allows deep infiltration of water and air. The porous, well-aerated soil also permits tree roots to penetrate deeply to reach the deep moisture. Small granite outcrops in the Tucson Mountains are of the finer-textured Laramide granite; trees do not grow as large on it as on coarser granite.

Soil explains much of the lushness of the tree growth in the Silverbell region. The reason for the greater diversity of plants associated with ironwood trees here compared with other regions of the Sonoran Desert is not known. The greater aridity of the Central Gulf Coast and Lower Colorado River Valley subregions may limit diversity, but the lower incidence of freezing temperatures in these subregions should foster greater diversity. There is no known cause for the lesser diversity of associates in the extensive ironwood forest on the bajadas of the Tortolita Mountains compared with the Silverbells.

In wetter years, six localities support dense carpets of annual wildflowers for which the Arizona Upland is renowned. These wildflower displays occur only in certain soil types, but little research has been done to characterize them. In general dense stands of annuals require moisture-retentive soils, such as sand dunes, silty-clayey soils, or soils with surface rocks that act as mulch. The coarse surface texture may also greatly decrease the foraging efficiency of seed-eating animals compared to fine-textured soils, thus fostering the accumulation of a larger seed bank and greater frequency of seeds of large-seeded annuals such as bladderpod and lupine compared to seed banks in fine-textured soils (Bob Schmalzel, pers. comm.).

In one area the annuals are consistently almost pure Mexican gold poppies. In some areas dense stands of this species seem to be correlated with copper-rich soils. Two other known poppy areas, Picacho Peak State Park and the bajada below Owlshead Butte in the Tortolita Mountains, are also known to be high in copper (Jim Briscoe, pers. comm.). The study area's poppy soil has not been analyzed, but it is derived from altered rock and is probably mineral-rich. On the other hand, lupines in the Silverbell area are common on the unaltered, less mineralized soils. (Figure 5)

There are four distinct assemblages of wildflower species in the various soils in the study area (Appendix III). It would be an excellent site to study the relationships between soils and particular annual plants.

Plants that grow on limestone must be adapted to low nutrient and water availability. The vegetation is thus sparse compared to that on other rock types in the same climate. The Watermans are mostly limestone, but contain outcrops of Cambrian quartzite. Saguaros there grow in densities several times greater than on the adjacent limestone.

The relative botanical richness varies among the ranges. Ragged Top's flora of 393 taxa is 24% richer than the 316 taxa expected on the basis of the area's size, elevational amplitude, and study effort, as projected by Bowers and McLaughlin (1982). The reason for this is most likely the extremely rugged terrain which creates more microclimates

Figure 5. Lupines on Ragged Top
A good show of Lupinus sparsiflorus on decomposed granite substrate on the east bajada of Ragged Top, in March of 1992.

than are found in the other three ranges. The Silverbells and Watermans have the expected number of species according to the same regression analysis. The Pan Quemados, a range of low, rounded hills within the study area, revealed a surprise. Their flora of 217 plants is 38% richer than expected; we cannot easily explain this anomaly with the currently available information.

Discussion

Vegetation ecology

A remarkable amount of plant ecological data has been collected in the Silverbell Mountains over the years; in fact, it can be argued that much of what we know about how Sonoran Desert plant communities function is derived from studies in the Silverbells and adjacent desert ranges (Solbrig et al. 1977; Simpson and Neff 1977). In the early 1970s, the U.S. International Biome Program (IBP) selected and leased a BLM site in the Silverbells as one of its two Sonoran Desert terrestrial validation sites, located in Section 21 R9E, T11S. In addition to correlating vegetation composition and biomass production with local climatic and soil conditions, ecologists initiated some of the first quantitative studies of plant/animal interactions in desertscrub vegetation. The following account highlights the results of the IBP studies (Thames 1972), and compares them with more recent analyses accomplished by the Arizona-Sonora Desert Museum and its Ironwood Alliance collaborators.

The first important principle confirmed at the IBP Silverbell Site was that there is extremely high variation in plant density and productivity from plot to plot, largely due to: 1) storm runoff and floodwater dispersion in rivulets and streams and streams affecting 15% of the entire area and 2) the development of five different soil types. In other words, different microenvironments offered heterogeneous conditions with respect to water availability, soil moisture holding capacity and fertility, which in turn created a complex vegetation mosaic. As Solbrig et al. (1977) summarized from their studies at the Silverbells: "Two characteristics of the warm deserts, obvious even to the casual observer, are the sparseness of plant cover and the diversity of life forms on bajada slopes Solbrig et al. (1977) confirm that mean distance between plants decrease upslope, and is inversely correlated with soil particle size. The authors concluded "all of these traits can be explained in principle by the effect of soil texture on water absorption and retention, the uneven precipitation, and the trade-offs between drought resistance and photosynthetic efficiency of different life forms."

McAuliffe (1999), wrote "the mosaic distribution of different-aged alluvial landforms and their associated soils often produces relatively abrupt discontinuities in vegetation composition". On the Silverbell piedmont, the explanation of the variance in the relative canopy cover of creosote bush among sites is found in soil differences among various geomorphic surfaces than by their position along the elevation gradient. Regardless of position along the gradient creosote bush density in the Silverbell area is correlated with the age of the surface. On mid-Holocene surfaces creosote bush has the highest density (80%), on late Holocene surfaces it is less prevalent (50%); and on Pleistocene surfaces with strong argillic horizons creosote bush has the lowest density (15-20%). Mid-late

Pleistocene surfaces, at any given elevation on the bajadas, support greater numbers of species than do any of the other geomorphic surfaces (McAuliffe 1994 and 1999).

The second important principle developed at the site is that the composition and biomass of woody perennials versus ephemeral annual wildflowers and grasses need to be studied on different spatial and temporal scales. Each of these sets of plants contributes to annual productivity and diversity in their own manner (Solbrig et al. 1977). In addition to several intensive studies of wildflowers at the Silverbell site, plant ecologists made some of the first measurements of the productivity and standing biomass of vegetative and reproductive organs of keystone species such as mesquite, paloverde and ironwood. The perennial plants on the IBP site which dominated most plots included the following species (their average densities cited): triangle-leafed bursage (1244 plants/hectare); creosote bush (92 pl/ha); little-leaf paloverde (27 pl/ha); white-thorn acacia (24 pl/ha); ironwood (14 pl/ha); and saguaro (7 pl/ha).

Nevertheless, there were large differences in the densities of these dominants found in upland versus channel (watercourse) sites, as the following data for ironwood indicate. In an 18-hectare area which off-road vehicle had passed over repeatedly to create a "perturbation treatment," upland plots averaged only 6.4 trees/ha whereas channel plots averaged 53.7 trees/ha. In untreated, less disturbed areas, upland plots averaged 12.7 tree/ha -- nearly twice that of disturbed plots -- and channel plots average 55.8 trees/ha. Vegetative cover of ironwoods in the upland plots, treated and untreated, was roughly a sixth of the vegetative cover in channeled plots receiving additional moisture from accumulated runoff. Ironwood cover for treated and untreated plots on channeled floodplains reached 1800-2000 foot elevation.

Although the IBP ecologists concluded "ironwood had a rather low density on the site" relative to creosote bush or triangle-leafed bursage, they quickly added, "because of the size of the trees, it was believed to make up a significant amount of the total biomass" (Table 1). In addition, they estimated that some of the ironwood trees on site were over 350 years of age, creating a "deep-rooted vegetation" with a "long survival record."

Table 1. Density and Biomass on the Silverbell Mountains
IBP Silverbell Bajada-site, Avra Valley, Pima County, Arizona.

Species	**Density (#/ha)**	**Biomass (kg/ha)**
Ambrosia deltoidea (triangle-leafed bursage)	1244	124.8
Larrea divaricata (creosote bush)	92	385.24
Cercidium microphyllum (littleleaf palo verde)	27	1032.4
Olneya tesota (ironwood)	14	2708.9

From International Biome Project 1972 data compiled by John L., Thames, University of Arizona

When the Arizona-Sonora Desert Museum team sampled ironwood habitat in the Silverbell-Ragged Top and Roskruge-Cocoraque Butte areas in the summer of 1999 (Nabhan et al. 2000), the team determined that these areas had high densities of ironwoods relative to other sites in the Sonoran Desert. The eight Ragged Top plots sampled averaged 35 pl/ha of ironwoods, and the eight Cocoraque Butte plots averaged 22 pl/ha, relative to a 15.2 pl/ha average cited by Solis-Garza and Espericueta (1997) in the summary of ironwood densities throughout northwestern Sonora. In addition, the four ironwood-centered plots at Ragged Top averaged over 25.5 plant species per 256 m2, compared to 22.5 species in random plots at the same site (Figure 6). These were by far the highest levels of species richness for any of the sixteen localities that we sampled in three sites, with Ragged Top contributing six of the ten richest plots in the entire region. The Cocoraque Butte site contributed two of the ten highest plots in terms of ecological importance values for ironwood, indicating that ironwood's presence greatly contributed to higher overall cover values for all species.

WILDLIFE

Overview

A total of 177 vertebrate species and at least 821 invertebrate species have been recorded in the study area. These numbers include several species federally listed as Threatened and Endangered as well as additional species of concern to Pima County's Sonoran Desert Protection Plan.

Unfortunately, these numbers are difficult to compare with those of other areas of comparable size, because of a lack of intensive sampling elsewhere. With regard to species at risk, this area is prime habitat for the desert bighorn sheep, a federally protected subspecies. The area is also historic and potential foraging habitat for two federally-listed animals, the cactus ferruginous pygmy owl and the lesser long-nosed bat. Several other vertebrate species in the area have been recommended for federal listing, but are not currently protected by the Endangered Species Act. Ten additional species recommended for inclusion in the Pima County Habitat Conservation Plan occur in the area: California leaf-nosed bat, Mexican long-tongued bat, lesser Long-nosed bat, western red bat, Merriam's mesquite mouse, Rufous-winged Sparrow, Tucson shovel-nosed snake, ground snake, and three talus snails (Figure 7).

Because of current interest of the Sectretary of Interior in protecting nectar corridors for migratory pollinators, these mountain ranges could form an important component of any binational plan to protect stopover habitat for hummingbirds, White-winged Doves and lesser long-nosed bats.

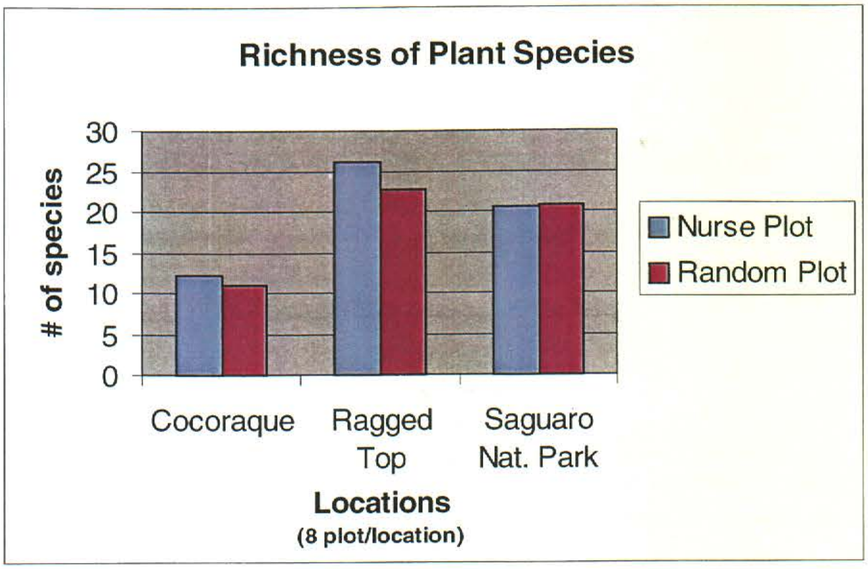


Figure 6. Species richness in ironwood habitat

Figure 7. Selected species of concern harbored in the study area Clockwise from top left: Nichol's turk's head cactus, cactus ferruginous pygmy owl, desert bighorn, desert tortoise.

As mentioned earlier, through the International Biome Program's inventories and subsequent studies, we have exceptionally thorough baseline of data on birds, mammals, and reptiles, including not only species lists, but also biomass estimates, seasonal densities, and assessment of community structure. The thoroughness of these data can provide unparalleled opportunities for measuring desert faunal changes through time.

Discussion

Mammals: The International Biome Project encountered 64 mammal species at its Silverbell site, and estimated nocturnal rodent biomass (Appendix V) to be higher than at their Santa Rita site. Since that time, several additional studies of particular wildlife species have been accomplished, enriching our knowledge of wildlife ecology for Arizona Upland in general. Bristow et al. (1996) investigated habitat use, behavior, movements, and demography of desert bighorn sheep on the northern portion of the ASARCO Silverbell Mine in the Silverbell and West Silverbell Mountains. They concluded that the "desert bighorn sheep within SBSA (Silverbell Study Area) represent the last viable desert bighorn sheep population indigenous of Tucson basin." It is worth identifying how unique the survival of desert bighorn sheep is in the Silverbell Mountains compared to many of the surrounding mountains. For example, in the Tucson Mountains there were still about 12 sheep in the 1940s; they have since been extirpated. The Santa Catalina Mountains (near Pusch Ridge) had about 50 bighorn sheep as late as the 1970s; these are now also extirpated. There is a potential for a significant dispersal of sheep between the Silverbell Mountains and mountains on the Tohono O'odham Reservation and Barry Goldwater Bombing Range. However, there are few sheep on the Reservation today. David Brown (Arizona Game and Fish report, unpublished) surveyed for all ungulates on the Tohono O'odham Reservation in 1984 and found only 9 bighorn sheep (along with 70 mule deer and 17,500 cattle, horses, and burros). The Silverbell bighorn sheep apparently established a breeding (lambing) population of sheep during the 1990s on the Waterman Mountains, but the population is now gone. The reasons why the populations of this species have declined or become extirpated may be industrial, urban and agricultural developments nearby (Krausman 1989).

Avifauna: In 1971, the International Biome Project (IBP) conducted studies of the avifauna on the Silverbell Site on a 50-acre study plot. Population sizes fluctuated from 59 species in June to 119 in December. In June, the White-winged Doves account for 45% of the total bird biomass on the plot. The White-winged Dove is an important pollinator of columnar cacti.

The reproductive success of breeding birds at Silverbell Site is shown in Table 2. It is important to highlight that the Silverbells are an area which migratory birds use not only as a stopover along their binational corridor, but also as nesting habitat. Appendix VI contains the list of birds found in the IBP studies summarized by Thames (1973). He reported the first breeding confirmation for Rufous-winged Sparrows in the region. In addition, Scott's Orioles and Harris Hawks attempted to breed there. Several other species, most notably Verdins, had high numbers of territories within the area.

Table 2. Reproductive success of bird in the Silverbell Mountains.

Species	Nests successful (%)	# of eggs	# of Nest
White-winged Dove	0.0	8	4
Mourning Dove	33.3	20	10
Gilded Flicker*	100.0	?	1
Gila Woodpecker*	100.0	?	2
Brown-crested Flycatcher*	100.0	?	1
Verdin	100.0	4	1
Cactus Wren*	80.0	14	5
Curve-billed thrasher	22.2	22	9
Black-tailed Gnatcatcher	0.0	6	6
Pyrrhuloxia	0.0	6	2
Brown Towhee	0.0	4	1
Black-throated Sparrow	0.0	5	2
Screech Owl*	100.0	?	1
Elf Owl*	100.0	?	1
Totals	25	89	40
* indicated cavity or closed nest			

From: IBP Silverbell site (1972), Avra Valley, Pima County, Arizona

Table 3. Invertebrates in the Waterman Mountains.

ORDER	Number of Families	Number of Species
ARANEA	8	9
BLATTARIA	2	3
COLEOPTERA	57	351
DIPTERA	17	49
HEMIPTERA	31	90
HYMENOPTERA	40	203
ISOPTERA	1	1
LEPIDOPTERA	14	35
MANTODEA	1	2
MICROCORYPHIA	1	1
NEUROPTERA	5	10
ODONATA	1	25
OPILIONES	1	1
PHASMATODEA	1	1
PSEUDOSCORPIONIDA	1	1
SCORPIONIDA	2	3
THYSANOPTERA	2	35
TRICHOPTERA	1	1

Olsen, Van Devender and Hall (unpublished data), University of Arizona

Reptiles, Amphibians and Fish: There are at least 62 reptile and amphibian species in the study area, as well as one native fish, the spiked dace. Schneider (1980) surveyed for desert tortoises near Ragged Top for the Bureau of Land Management. In 1991, the Arizona-Game and Fish Department established a permanent plot in the Silverbell Mountains to study the population ecology of the desert tortoise (Hart et al. 1992; Woodman et al. 1996). In addition, zoologists have found a number of Lower Colorado River Valley animals, including banded sand snake, chuckwalla, desert horned lizard, desert iguana, leaf-nosed snakes, long-tailed brush lizard, and sidewinders, which reach their eastern limits in these mountains or the nearby Avra Valley.

Invertebrates: Beryl Simpson and Jack Neff developed a rather complete invertebrate inventory for the Silverbell Mountains during the 1970s and 1980s (Simpson and Neff 1987). Carl Olson worked on an arthropod inventory in the Waterman Mountains in the late 1980's. He identified species in 18 Orders, 186 Families, and 821 taxa (Table 3). His results show that beetles are unusually well represented here. The large number of families and species present in this area indicate the diverse range of invertebrate species that in turn support a large number of birds and reptiles.

W. Eugene Hall (unpublished data) identified fossil arthropods recovered from the packrat middens originally collected and analyzed for the vegetational history of the Waterman Mountains (Anderson and Van Devender 1991; Van Devender 1990). The fossil arachnids (scorpions, spiders, solpugids, pseudoscorpions, etc.) were identified to 5 orders, 7 families, 3 genera and 1 species; myriapods (centipedes millipedes) 2 orders; and crustaceans by 1 isopod (sowbug). In the insect fauna, 32 families (16 beetles), 56 genera (33 beetles), and 52 species (32 beetles) were identified.

RESEARCH HISTORY

Overview

The study area has a long history of research in many fields and is a prime candidate for use as a long-term ecosystem research area to monitor environmental change. More botanical studies have been done on Tumamoc Hill (the Desert Laboratory of the University of Arizona), but more desert ecosystem research has been done in the Silverbell area. Tumamoc Hill has been significantly impacted by urban encroachment and is no longer a pristine environment.

The study area provides an excellent baseline for continued research on long-term changes in a natural environment. Though the copper mines have rather large footprints and visual scars on the landscape, their ecological impact to the surrounding land appears to be minor. The study area is easily accessible from Tucson, and, depending on the kind of preserve designated, there may be fewer restrictions on research than in other protected natural areas.

Conservation significance
Based on the number of species at risk, the study area is ranked among the top 40 conservation target sites in the Sonoran Desert Ecoregion, and among the top 20 in Arizona's portion of the region (Marshall et al. 2000). It is also featured as a proposed reserve in the conceptual reserve design for the entire Sonoran Desert proposed by the Wildlands Project (Turner 1999). Together with the Baboquivaris, these ranges form a nearly unbroken upland corridor from rural Mexico essential to any future network of desert reserves.

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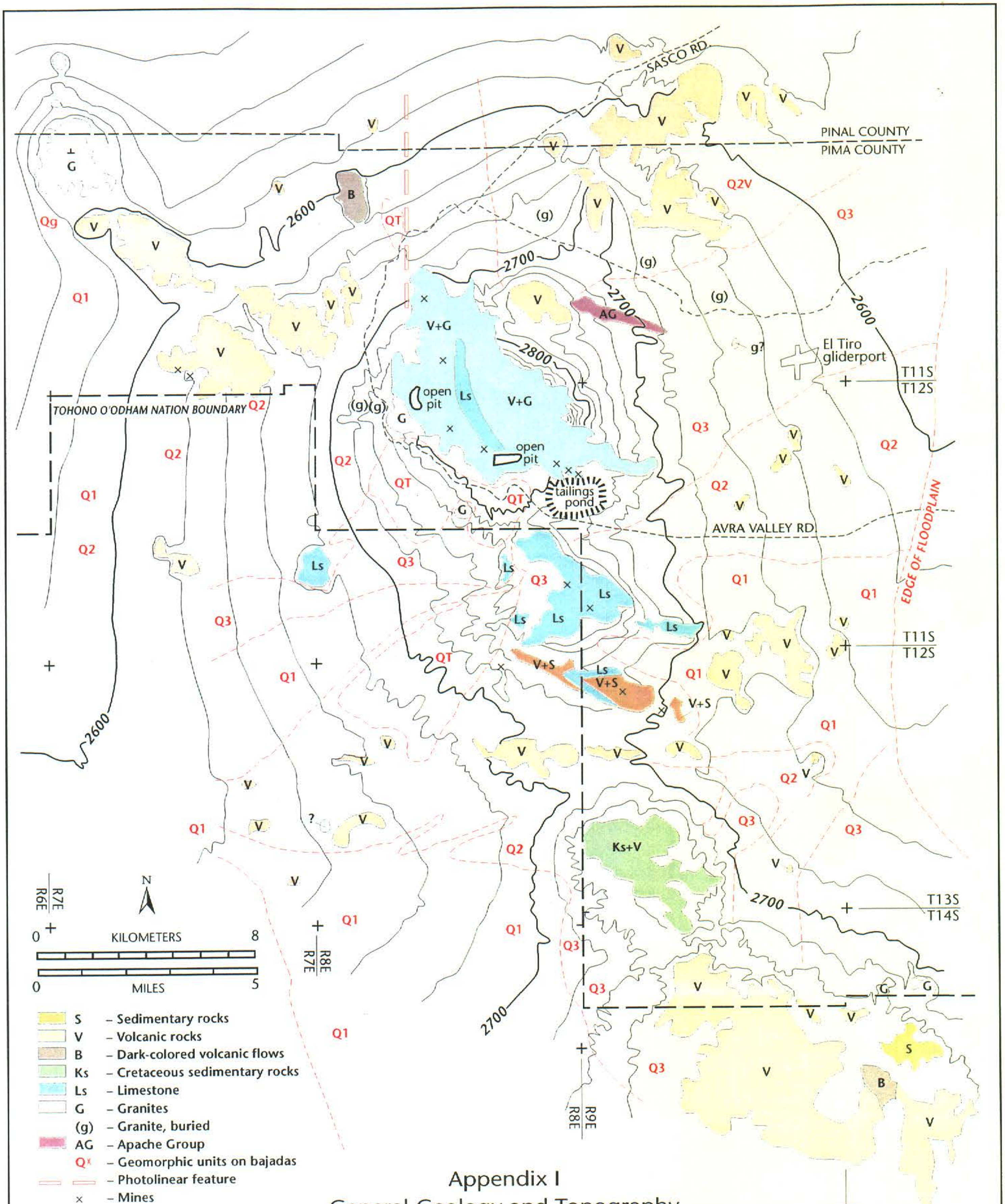


Appendix I

General Geology and Topography

EXPOSED ROCK AND SOILS

SILVERBELL, WATERMAN AND ROSKRUGE MOUNTAINS

Pima County, Arizona

Generalized bedrock geology

S Lithified sedimentary rocks, mostly sandstones, shales, conglomerates

V Volcanic rocks - flows, tuffs, ash beds, typically weathers to cliffs and mesas, mostly of rhyolite composition and fairly resistant to erosion. Two sequences present, Laramide and mid-Tertiary.

B Dark-colored volcanic flows (basalt, etc.) such as at Malpais Hill and Recortado Butte. The rocks are mid-Tertiary in age.

Ks Cretaceous-age sedimentary rocks - weakly lithified arkose and conglomerate

Ls Limestone with lesser quartzite, shale (Paleozoic series)

G Granites, mixed age, composition, weatherability

(g) granite, buried at shallow depths under pediment surfaces

AG Quartzites, shales, minor limestones of the Precambrian-age Apache Group

Geomorphic Units on the Bajadas

note: These generalized divisions of bajada surfaces were compiled by inspection of an enhanced-color LANDSAT image (scale about 1:62,500), with very limited field checking. Fundamentally, surfaces were discriminated on the basis of degree of dissection and general color. The divisions are not meant to imply quantitative categorizations, nor equivalency with ages or units defined by field mapping techniques.

Q1 Younger surfaces near the level of modern streams, with immature soils and lighter surface colors, subject to flooding and sheetwash processes. These surfaces widen towards and merge with the edge of valley axial floodplains. Some areas on the map or directly adjacent areas apparently contain vegetated sand dunes, or fluvially redeposited beds containing eolian sand, as along the southeastern flank of the Waterman Mountains west of the Pan Quemado hills.

Q2 Intermediate-age surfaces as indicated by darker colors on photo, in some instances standing above modern washes by 1-2 meters, consisting of either a flat and unincised surface with evidence for occasional sheet flooding, or with capping pavements caused by ablation, or with bar-and-swale relief, implying relict alluvial fan braidplain deposition.

Q3 Bajadas containing older surface remnants elevated by 3-6 m above stream channels, capped with mature soils and slightly darkened pavements, which overlie exposed thicknesses of Quaternary alluvium. These composite surfaces lie close to mountain fronts, and represent older Pleistocene alluvial fan remnants whose distal ends merge with younger alluvium, and increasingly incised by modern channels towards proximal (upslope) parts. Contain moderate development of desert pavement surfaces with moderate brown-tan varnish on rocks, which imparts distinct darker tones on enhanced aerial photos.

QT Bajadas containing older remnant surfaces elevated by as much as 10-20 m above modern stream channels, incised by younger lower-elevation surfaces which are in turn incised by modern arroyos. These are seen only on the western, and to a lesser degree on the northern flank of the Silverbell Mountains. One quite narrow terrace remnant along Avra Valley Road near the Silver Bell mine was seen to lack a significant capping relict soil. However, remnant eroded angular fragments of dense caliche 2-4 cm diameters were seen littering the surface, implying recent removal of the soil cap by recent erosion. Quaternary alluvium exposed on terrace flanks and in nearby roadcuts consists of a capping layer of coarse gravels with rounded boulders to 1 m diameter, and lower beds clearly of debris flow origin mixed with beds of coarse fluvial laminar-bedded sorted pebbly sands.

(Open-box red dashed line pattern) Photolinear feature in the northern Silver Bell Mountains that separates reddish soils on the east from green-gray soils on the west, with hints of structural control of stream patterns from a buried north-south trending structure.

Appendix II: Flora of the study area

Compilation of individual floras from ranges & hills within the proposed Ironwood Preserve area (Roskruge Mts, north to the Pinal County line. This includes a comparison with the nearby Tucson Mts. (including Saguaro National Park) and Organpipe National Monument.

Roskruge Mts. (RM); Waterman Mts. (WM); Pan Quemado (PQ); Silver Bell Mts. (SB); Ragged Top (RT); Red Hill (RH); Samaniego Hills (SH); Malpais Hill (MH); Organ Pipe National Monument; Tucson Mts. (incl. Saguaro NP West)

■ = found in OPNM
● = found in Tucson Mts.
[shaded] = non-native species

RM	WM	PQ	SB	RT	RH	SH	MH	OPNM	Tucson Mts.	Species
										Acanthaceae
			SB	RT				■	●	*Anisacanthus thurberi*
RM	WM	PQ	SB	RT		SH		■	●	*Carlowrightia arizonica*
				RT				■	●	*Justicia californica*
		PQ	SB					■	●	*Ruellia nudiflora*
RM	WM	PQ	SB	RT		SH		■	●	*Siphonoglossa longiflora*
										Adiantaceae
RM	WM	PQ	SB	RT	RH	SH			●	*Astrolepis cochisensis*
	WM									*Astrolepis jonesii*
RM	WM	PQ	SB	RT		SH		■	●	*Astrolepis sinuata*
RM	WM	PQ	SB	RT		SH		■	●	*Cheilanthes lindheimeri*
	WM									*Cheilanthes villosa*
		PQ	SB	RT		SH		■	●	*Cheilanthes wootoni*
RM	WM	PQ	SB	RT		SH		■	●	*Cheilanthes wrightii*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Notholaena standleyi*
	WM	PQ	SB	RT		SH		■	●	*Pellaea truncata*
				RT				■		*Pityrogramma triangularis*
										Agavaceae
	WM		SB					■		*Agave deserti*
	WM		SB	RT				■	●	*Yucca arizonica*
										Aizoaceae
	WM							■	●	*Trianthema portulacastrum*
										Amaranthaceae
				RT						*Amaranthus albus*
RM		PQ	SB	RT		SH	MH	■	●	*Amaranthus fimbriatus*
RM	WM	PQ	SB	RT				■	●	*Amaranthus palmeri*
	WM		SB	RT					●	*Amaranthus tucsonensis*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Tidestroemia lanuginosus*
										Apiaceae
RM	WM	PQ	SB	RT	RH	SH		■	●	*Bowlesia incana*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Daucus pusillus*

	WM		SB	RT				■	●	*Spermolepis echinata*
				RT		SH			●	*Yabea microcarpa*
										Apocynaceae
RM	WM	PQ	SB	RT				■	●	*Haplophyton cimcidum*
										Aristolochiaceae
	WM			RT				■	●	*Aristilochia watsoni*
										Asclepiadaceae
				RT				■		*Asclepias linaria*
	WM			RT		SH			●	*Asclepias nyctaginifolia*
RM	WM		SB	RT				■	●	*Cynanchum arizonicum*
				RT						*Matelea arizonica*
	WM		SB	RT		SH		■	●	*Matelea parvifolia*
		PQ							●	*Matelea producta*
RM			SB	RT		SH		■	●	*Sarcostemma cynanchoides*
										Asteraceae
	WM	PQ		RT		SH		■	●	*Acourtia nana*
RM	WM	PQ	SB	RT		SH		■	●	*Acourtia wrightii*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Ambrosia ambrosioides*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Ambrosia confertiflora*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Ambrosia deltoidea*
RM	WM	PQ	SB	RT				■	●	*Ambrosia dumosa*
			SB					■	●	*Artemesia ludoviciana*
RM										*Aster spinosus*
RM								■	●	*Baccharis salicifolia*
RM		PQ	SB	RT		SH		■	●	*Baccharis sarothroides*
	WM								●	*Bahia absinthifolia*
RM	WM	PQ	SB	RT		SH		■	●	*Baileya multiradiata*
RM		PQ	SB	RT		SH	MH	■	●	*Bebbia juncea*
	WM		SB	RT					●	*Brickellia baccharidea*
				RT				■	●	*Brickellia californica*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Brickellia coulteri*
	WM	PQ	SB	RT		SH		■	●	*Calycoseris wrightii*
			SB						●	*Centaurea melitensis*
	WM	PQ		RT		SH		■	●	*Chaenactis carphoclinia*
				RT	RH			■	●	*Chenactis stevioides*
			SB					■	●	*Conyza canadensis*
		PQ							●	*Conyza coulteri*
	WM		SB	RT					●	*Dyssodia pentachaeta*
RM	WM		SB	RT	RH	SH		■	●	*Dyssodia porophylloides*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Encelia farinosa v. farinosa*
				RT				■	●	*Ericameria cuneata*
RM	WM		SB	RT		SH		■	●	*Ericameria laricifolia*
	WM	PQ	SB	RT		SH		■	●	*Erigeron divergens*
			SB	RT		SH		■	●	*Erigeron lobatus*
	WM	PQ	SB	RT	RH	SH		■	●	*Eriophyllum lanosum*
	WM		SB	RT				■	●	*Eupatorium solidaginifolium*
	WM								●	*Evax multicaulis*
RM				RT				■	●	*Filago arizonica*
		PQ	SB	RT	RH	SH		■	●	*Filago californica*

				RT	RH	SH		■	●	*Filago depressa*
		PQ						■	●	*Gaillardia arizonica*
	WM							■		*Geraea canescens*
				RT				■	●	*Gnaphalium wrightii*
		PQ							●	*Gutierrezia microcephala*
	WM	PQ	SB	RT				■	●	*Gymnosperma glutinosum*
				RT		SH			●	*Helianthus petiolaris ssp. fallax*
	WM	PQ	SB	RT					●	*Heterotheca subaxillaris*
			SB	RT		SH	MH	■	●	*Hymenoclea salsola v. pentalepis*
				RT				■	●	*Hymenothrix wislizeni*
RM	WM	PQ	SB	RT		SH			●	*Isocoma tenuisecta*
RM		PQ	SB	RT		SH		■	●	*Lactuca serriola*
	WM							■	●	*Macharanthera gracilis*
	WM	PQ	SB	RT		SH	MH	■	●	*Macharanthera pinnatifida ssp. pinnatifida*
RM			SB					■	●	*Macharanthera tagetina*
				RT				■	●	*Malacothrix californica v. glabrata*
	WM			RT		SH		■	●	*Malacothrix clevelandi*
				RT					●	*Matricaria matricarioides*
		PQ		RT	RH	SH		■	●	*Microseris linearifolia*
	WM	PQ	SB	RT	RH			■	●	*Monoptilon bellioides*
	WM								●	*Parthenium incanum*
			SB	RT		SH			●	*Pectis cylindrica*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Pectis papposa*
		PQ		RT	RH	SH		■	●	*Perityle emoryi*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Porophyllum gracile*
RM	WM	PQ		RT		SH		■	●	*Psilostrophe cooperi*
				RT				■	●	*Rafinesquia californica*
	WM	PQ	SB	RT		SH		■	●	*Rafinesquia neomexicana*
	WM			RT					●	*Senecio douglasii v. monoensis*
RM	WM	PQ	SB	RT		SH		■	●	*Senecio lemmoni*
				RT						*Silybum marianum*
				RT				■	●	*Sonchus asper*
	WM		SB	RT		SH		■	●	*Sonchus oleraceus*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Stephanomeria pauciflora*
				RT					●	*Stylocline gnaphalioides*
RM	WM	PQ		RT	RH	SH		■	●	*Stylocline micropoides*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Trixis californica*
				RT				■		*Viguiera deltoidea v. parishii*
	WM		SB						●	*Xanthium strumarium*
RM	WM	PQ	SB	RT		SH		■	●	*Zinnia acerosa*
										Boraginaceae
RM	WM	PQ	SB	RT	RH	SH			●	*Amsinckia intermedia*
		PQ	SB	RT	RH	SH		■	●	*Amsinckia tesselata*
				RT				■	●	*Cryptantha angustifolia*
	WM	PQ	SB	RT	RH	SH		■	●	*Cryptantha barbigera*
				RT					●	*Cryptantha decipiens*
		PQ						■	●	*Cryptantha maritima*
		PQ							●	*Cryptantha micrantha*
RM		PQ		RT	RH	SH			●	*Cryptantha nevadensis*

RM	WM	PQ	SB	RT	RH	SH		■	●	*Cryptantha pterocarya*
	WM	PQ	SB	RT		SH		■	●	*Harpagonella palmeri*
	WM	PQ	SB	RT				■	●	*Lappula redowskii*
				RT				■	●	*Pectocarya heterocarpa*
	WM	PQ		RT		SH		■	●	*Pectocarya platycarpa*
	WM	PQ	SB	RT	RH	SH		■	●	*Pectocarya recurvata*
		PQ		RT		SH			●	*Plagiobothrys arizonica*
		PQ			RH	SH			●	*Plagiobothrys pringlei*
	WM		SB	RT				■	●	*Tiquilia canescens*
										Brassicaceae
RM	WM	PQ	SB	RT				■	●	*Arabis perennans*
RM			SB	RT				■	●	*Brassica tournfortii*
				RT					●	*Capsella bursa-pastoris*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Caulanthus lasiophyllus*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Descurainia pinnata*
RM	WM	PQ	SB	RT		SH		■	●	*Draba cuneifolia*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Lepidium lasiocarpum*
	WM	PQ	SB	RT	RH	SH		■	●	*Lesquerella gordonii*
				RT					●	*Lesquerella purpurea*
	WM		SB						●	*Matthiola longipetala v. bicornis*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Sisymbrium irio*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Streptanthus carinatus*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Thysanocarpus curvipes*
										Burseraceae
	WM							■		*Bursera microphylla*
										Cactaceae
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Carnegiea gigantea*
	WM									*Echinocactus horizonthalonius v. nicholii*
RM		PQ	SB	RT		SH	MH			*Echinocereus engelmannii v. acicularis*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Echinocereus fendleri v. robustus*
	WM		SB	RT			MH	■		*Echinocereus nicholii*
RM	WM	PQ				SH	MH	■	●	*Ferocactus cylindraceous*
				RT					●	*Ferocactus cylindraceous x F. wislizeni*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Ferocactus wislizeni*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Mammillaria grahamii v. microcarpa*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Opuntia acanthocarpa v. major*
	WM	PQ								*Opuntia acanthocarpa x O. leptocaulis*
RM							MH	■	●	*Opuntia arbuscula*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Opuntia bigelovii*
RM	WM	PQ	SB	RT				■	●	*Opuntia chlorotica*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Opuntia engelmannii*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Opuntia fulgida v. fulgida*
RM	WM		SB						●	*Opuntia fulgida v. mammillata*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Opuntia leptocaulis*
				RT				■		*Opuntia leptocaulis x O. fulgida*
RM	WM		SB	RT	RH					*Opuntia macrocentra*
				RT					●	*Opuntia microdasys (not persistant)*
RM	WM	PQ	SB	RT		SH		■	●	*Opuntia phaeacantha v. major*
				RT					●	*Opuntia santa-rita*

RM	WM	PQ	SB	RT	RH	SH	MH	■	●	Taxon
RM	WM	PQ	SB			SH		■	●	*Opuntia spinosior*
RM			SB	RT					●	*Opuntia spinosior x O. versicolor*
			SB							*Opuntia sp. (white-spined ? acanthocarpa)*
RM								■	●	*Opuntia versicolor*
	WM		SB					■	●	*Peniocereus greggii*
										Campanulaceae
RM	WM	PQ		RT	RH			■	●	*Nemacladus glanduliferus*
										Cannabaceae
				RT					●	*Cannabis sativa (not persistant)*
										Capparidaceae
	WM								●	*Koeberlinia spinosa*
										Caprifoliaceae
	WM		SB						●	*Sambucus mexicana*
										Caryophyllaceae
				RT				■		*Cerastium texanum*
	WM			RT					●	*Herniaria cinerea*
				RT					●	*Loeflingia squarrosa*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Silene antirrhina*
										Chenopodiaceae
RM	WM	PQ	SB	RT		SH		■	●	*Atriplex canescens*
						SH				*Atriplex canescens x A. polycarpa*
	WM		SB	RT				■	●	*Atriplex elegans*
				RT				■	●	*Atriplex linearis*
	WM							■	●	*Chenopodium murale*
RM	WM	PQ	SB	RT		SH			●	*Chenopodium neomexicanum*
						SH				*Chenopodium sp.*
				RT					●	*Monolepis nuttaliana*
	WM		SB	RT				■	●	*Salsola australis*
										Convolvulaceae
RM	WM	PQ	SB	RT				■	●	*Evolvulus alsinoides*
			SB	RT					●	*Ipomoea cristulata*
RM	WM		SB	RT					●	*Ipomoea hederacea*
										Crassulaceae
		PQ	SB	RT		SH		■	●	*Crassula connata*
	WM							■		*Graptopetalum rusbyi*
										Crossosomataceae
	WM		SB	RT				■	●	*Crossosoma bigelovii*
										Cucurbitaceae
				RT				■	●	*Cucurbita digitata*
			SB	RT					●	*Echinopepon wrightii*
				RT				■	●	*Tumamocha macdougalii*
										Ephedraceae
	WM	PQ	SB						●	*Ephedra nevadensis*
RM		PQ	SB	RT		SH			●	*Ephedra trifurca*
										Euphorbiaceae
	WM		SB	RT					●	*Bernardia incana*
RM	WM		SB	RT				■		*Croton sonorae*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Ditaxis lanceolata*

RM	WM	PQ	SB	RT	RH	SH	MH	■	●	Species
RM	WM	PQ	SB	RT		SH	MH	■	●	*Ditaxis neomexica*
	WM		SB	RT					●	*Euphorbia abramsiana*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Euphorbia arizonica*
RM	WM	PQ	SB	RT		SH		■	●	*Euphorbia capitellata*
RM	WM		SB	RT		SH	MH	■	●	*Euphorbia eriantha*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Euphorbia florida*
			SB	RT		SH	MH		●	*Euphorbia gracillima*
				RT					●	*Euphorbia heterophylla*
	WM		SB	RT					●	*Euphorbia hyssopifolia*
		PQ	SB	RT	RH	SH		■	●	*Euphorbia melanadenia*
	WM			RT					●	*Euphorbia micromera*
	WM		SB	RT				■	●	*Euphorbia pediculifera*
RM		PQ	SB	RT		SH	MH	■	●	*Euphorbia polycarpa*
	WM									*Euphorbia revoluta*
RM	WM		SB	RT		SH	MH	■	●	*Euphorbia setiloba*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Jatropha cardiophylla*
	WM			RT		SH		■	●	*Tragia nepetaefolia*
										Fabaceae
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Acacia constricta*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Acacia greggii v. arizonica*
RM			SB						●	*Astragalus arizonicus*
		PQ	SB	RT	RH	SH			●	*Astragalus didymocarpus*
				RT		SH			●	*Astragalus lentiginosus v. australis*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Astragalus nuttallianus v. austrinus*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Calliandra eriophylla*
RM	WM		SB	RT		SH		■	●	*Cercidium floridum*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Cercidium microphyllum*
RM		PQ		RT				■	●	*Coursettia glandulosa*
	WM							■		*Dalea mollis*
	WM							■	●	*Dalea neomexicana*
				RT		SH		■	●	*Desmodium procumbens v. exiguum*
				RT				■	●	*Galactia wrightii*
				RT					●	*Hoffmanseggia glauca*
	WM	PQ	SB	RT	RH	SH		■	●	*Lotus humistratus*
RM								■	●	*Lotus rigidus*
	WM	PQ	SB	RT	RH	SH		■	●	*Lotus salsuginosus v. brevivexillus*
	WM	PQ	SB	RT	RH	SH		■	●	*Lotus strigosus v. tomentellus*
						SH		■	●	*Lupinus concinnus*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Lupinus sparsiflorus*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Marina parryi*
RM								■	●	*Melilotus indicus*
	WM	PQ	SB					■	●	*Nissolia schottii*
RM	WM		SB	RT		SH	MH	■	●	*Olneya tesota*
			SB						●	*Parkinsonia aculeata*
				RT					●	*Phaseolus acutifolius v. tenuifolius*
				RT		SH		■	●	*Phaseolus filiformis*
RM	WM	PQ	SB	RT		SH		■	●	*Prosopis velutina*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Senna covesii*
	WM	PQ		RT					●	*Vicia ludoviciana*

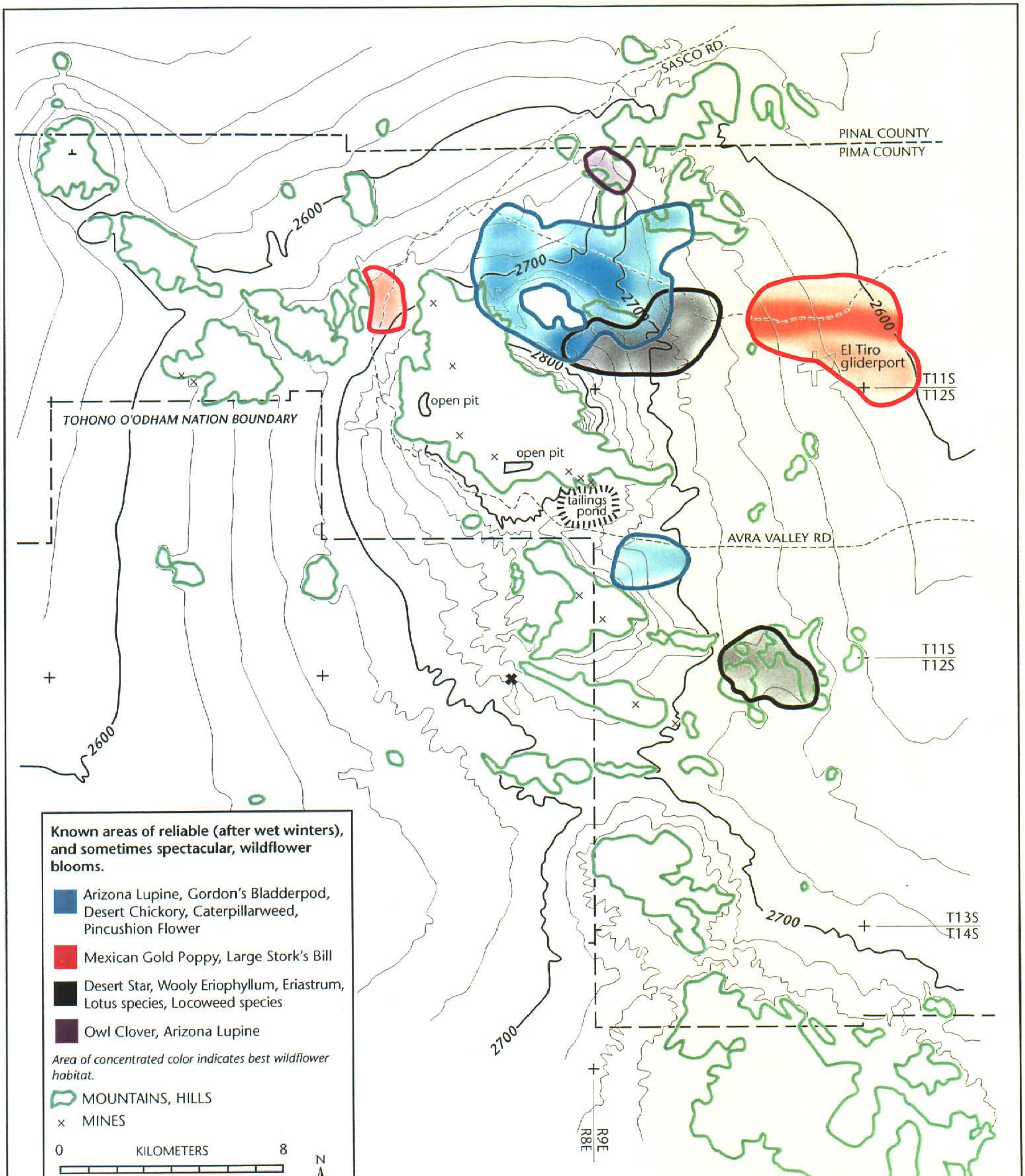
										Fagaceae
				RT					●	*Quercus turbinella*
										Fouquieriaceae
RM	WM	PQ	SB	RT	RH	SH		■	●	*Fouquieria splendens*
										Fumariaceae
				RT						*Fumena parviflora*
										Geraniaceae
RM	WM	PQ	SB	RT	RH	SH		■	●	*Erodium cicutarium*
	WM	PQ	SB	RT	RH	SH		■	●	*Erodium texanum*
										Hydrophyllaceae
	WM	PQ	SB	RT	RH	SH		■	●	*Eucrypta chrysanthemifolia*
RM	WM	PQ	SB	RT	RH			■	●	*Eucrypta micrantha*
	WM			RT				■	●	*Nama hispidum*
				RT				■	●	*Phacelia affinis*
	WM			RT				■	●	*Phacelia coerulea*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Phacelia crenulata*
				RT						*Phacelia cryptantha*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Phacelia distans v. australis*
	WM	PQ	SB	RT		SH		■	●	*Pholistoma auritum v. arizonicum*
										Juncaceae
				RT				■		*Juncus bufonius*
										Krameriaceae
RM	WM	PQ	SB	RT	RH	SH		■	●	*Krameria erecta v. glandulosa*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Krameria grayi*
										Lamiaceae
	WM		SB	RT				■	●	*Hedeoma nanum ssp. macrocalyx*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Hyptis emoryi*
	WM			RT				■		*Monardella arizonica*
	WM	PQ	SB	RT	RH	SH		■	●	*Salvia columbariae*
				RT						*Stachys coccinea*
		PQ							●	*Teucrium cubense ssp depressum*
										Liliaceae
	WM		SB	RT				■	●	*Allium macropetalum*
RM		PQ	SB	RT				■	●	*Calochortus kennedyi*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Dichelostemma pulchellum*
										Linaceae
	WM			RT					●	*Linum lewisii*
										Loasaceae
			SB	RT					●	*Mentzelia affinis*
	WM							■	●	*Mentzelia cf. albicaulis*
	WM			RT				■		*Mentzelia involucrata*
			SB							*Mentzelia pumila*
										Malpighiaceae
RM	WM	PQ	SB	RT	RH	SH		■	●	*Janusia gracilis*
										Malvaceae
				RT	RH				●	*Abutilon abutiloides*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Abutilon incanum*
RM	WM	PQ	SB	RT		SH			●	*Abutilon malacum*
				RT						*Abutilon mollicomum*

				RT					●	*Abutilon parishii*
				RT					●	*Abutilon parvulum*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Herissantia crispa*
				RT					●	*Hibiscus biseptus*
RM	WM	PQ	SB	RT		SH		■	●	*Hibiscus coulteri*
RM	WM		SB	RT				■	●	*Hibiscus denudatus*
	WM	PQ	SB	RT		SH	MH	■	●	*Horsfordia newberryi*
		PQ		RT		SH		■	●	*Malva parviflora*
				RT				■	●	*Malvastrum bicuspidatum*
RM			SB	RT				■	●	*Sida abutifolia*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Sphaeralcea ambigua v. rosei*
				RT						*Sphaeralcea ambigua x S. emoryi*
	WM	PQ	SB	RT				■	●	*Sphaeralcea coulteri*
		PQ	SB					■	●	*Sphaeralcea emoryi v. californica*
			SB	RT		SH		■	●	*Sphaeralcea laxa*
				RT					●	*Sphaeralcea subhastata v. thyrsoidea*
	WM									*Sphaeralcea sp (tall, orange flower)*
										Molluginaceae
				RT					●	*Mollugo verticillata*
										Nyctaginaceae
RM	WM	PQ	SB	RT		SH	MH	■	●	*Allionia incarnata*
RM			SB	RT		SH		■	●	*Boerhavia coccinea*
				RT					●	*Boerhavia coulteri*
RM				RT	RH	SH		■	●	*Boerhavia erecta*
		PQ	SB	RT					●	*Boerhavia intermedia*
				RT					●	*Boerhavia spicata*
	WM			RT				■	●	*Boerhavia wrightii*
RM	WM	PQ	SB	RT		SH		■	●	*Commicarpus scandens*
	WM	PQ	SB	RT	RH	SH	MH	■	●	*Mirabilis bigelovii*
				RT						*Pisonia capitata*
										Olaceae
			SB	RT				■	●	*Forestiera shrevei*
RM	WM	PQ	SB	RT		SH		■	●	*Menodora scabra*
										Onagraceae
	WM			RT				■		*Camissonia boothii*
RM		PQ	SB	RT		SH		■	●	*Camissonia californica*
RM	WM		SB	RT				■	●	*Camissonia chamaenerioides*
				RT				■	●	*Camissonia clavaeformis ssp. cooperi*
	WM									*Oenothera albicaulis*
		PQ	SB	RT		SH	MH	■	●	*Oenothera primiveris*
										Orobanchaceae
		PQ		RT		SH		■	●	*Orobanche ludoviciana ssp. cooperi*
										Papaveraceae
		PQ	SB					■	●	*Argemone gracilenta*
				RT		SH			●	*Argemone ochroleuca*
RM		PQ	SB	RT	RH	SH		■	●	*Eschscholtzia mexicana*
										Pedaliaceae
				RT		SH			●	*Proboscidea althaeafolia*
				RT					●	*Proboscidea parviflora*

										Plantaginaceae
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Plantago fastigiata*
	WM									*Plantago major*
	WM	PQ	SB	RT		SH		■	●	*Plantago patagonica*
										Plumbaginaceae
				RT				■	●	*Plumbago scandens*
										Poaceae
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Aristida adscensionis*
		PQ	SB	RT				■	●	*Aristida parishii*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Aristida purpurea v. nealleyi*
	WM			RT					●	*Aristida purpurea v. purpurea*
			SB	RT					●	*Aristida ternipes v. hamulosa*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Aristida ternipes v. ternipes*
RM	WM		SB	RT				■	●	*Bothriochloa barbinodis*
RM										*cf. Bothriochloa*
RM	WM		SB	RT		SH		■	●	*Bouteloua aristidoides v. aristidoides*
RM	WM		SB	RT	RH	SH	MH	■	●	*Bouteloua barbata*
RM	WM	PQ	SB	RT		SH		■	●	*Bouteloua curtipendula*
	WM								●	*Bouteloua eriopoda*
RM	WM	PQ	SB	RT				■	●	*Bouteloua repens*
			SB	RT			MH	■	●	*Bouteloua rothrockii*
RM	WM		SB	RT					●	*Bouteloua trifida*
	WM	PQ	SB	RT		SH	MH		●	*Brachiaria arizonica*
	WM			RT		SH		■	●	*Bromus carinatus*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Bromus rubens*
				RT						*Cathestecum brevifolium*
		PQ		RT				■	●	*Chloris virgata*
	WM		SB	RT				■	●	*Cottea pappophoroides*
RM	WM		SB	RT				■	●	*Cynodon dactylon*
RM	WM	PQ	SB	RT	RH	SH	MH		●	*Digitaria californica*
				RT						*Digitaria cognata*
				RT					●	*Digitaria insularis*
			SB	RT				■	●	*Elymus elymoides*
	WM								●	*Enneapogon cenchroides*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Enneapogon desvauxii*
			SB						●	*Eragrostis barrelieri*
RM	WM		SB	RT		SH		■	●	*Eragrostis cilianensis*
				RT				■	●	*Eragrostis intermedia*
RM		PQ	SB	RT		SH			●	*Eragrostis lehmanniana*
				RT		SH			●	*Eragrostis pectinacea*
			SB						●	*Eriochloa acuminata*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Erioneuron pulchellum*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Heteropogon contortus*
RM	WM	PQ	SB					■	●	*Hilaria belangeri*
	WM			RT		SH		■	●	*Hordeum murinum ssp. glaucum*
			SB	RT				■	●	*Leptochloa dubia*
RM	WM	PQ	SB	RT		SH	MH	■	●	*Leptochloa mucronata*
				RT				■	●	*Muhlenbergia emersleyi*
	WM	PQ	SB	RT		SH	MH	■	●	*Muhlenbergia microsperma*

				RT					●	*Muhlenbergia monticola*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Muhlenbergia porteri*
				RT				■	●	*Muhlenbergia rigens*
	WM									*Panicum hallii*
	WM		SB	RT				■	●	*Panicum hirticaule*
	WM							■	●	*Panicum obtusum*
RM	WM	PQ	SB	RT					●	*Pappophorum mucronulatum*
	WM		SB					■	●	*Pennisetum ciliare*
				RT						*Phalaris canariensis*
	WM			RT		SH		■	●	*Phalaris minor*
	WM							■	●	*Phragmites australis*
	WM	PQ	SB	RT	RH	SH		■	●	*Poa bigelovii*
			SB					■	●	*Polypogon monspeliensis*
RM	WM	PQ		RT	RH	SH	MH	■	●	*Schismus barbatus*
			SB	RT		SH			●	*Setaria grisebachii*
	WM	PQ	SB	RT		SH	MH		●	*Setaria leucopila*
			SB	RT				■	●	*Setaria macrostachya*
				RT						*Sorghum bicolor (not persistant)*
			SB						●	*Sorghum halepense*
				RT				■	●	*Sporobolis airoides*
RM	WM		SB						●	*Sporobolis contractus*
RM	WM		SB	RT				■	●	*Sporobolis cryptandrus*
			SB	RT					●	*Sporobolis wrightii*
				RT				■	●	*Stipa speciosa*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Tridens muticus*
	WM			RT					●	*Trisetum interruptum*
				RT					●	*Vulpia microstachys*
				RT					●	*Vulpia octoflora v. hirtella*
RM	WM	PQ	SB	RT		SH		■	●	*Vulpia octoflora v. octoflora*
										Polemoniaceae
RM	WM	PQ	SB	RT		SH	MH	■	●	*Eriastrum diffusum*
	WM	PQ	SB	RT	RH	SH			●	*Gilia flavocinta ssp. australis*
RM	WM	PQ	SB	RT	RH	SH			●	*Gilia stellata*
				RT						*Gilia stellata x G. scopulorum*
				RT						*Ipomopsis multiflora*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Linanthus bigelovii*
										Polygalaceae
RM	WM	PQ		RT				■	●	*Polygala macradenia*
										Polygonaceae
RM	WM	PQ	SB	RT	RH	SH		■	●	*Chorizanthe brevicornu*
RM	WM	PQ	SB	RT		SH		■	●	*Chorizanthe rigida*
RM	WM	PQ	SB	RT				■	●	*Eriogonum abertianum*
RM	WM	PQ	SB	RT				■	●	*Eriogonum deflexum*
			SB	RT		SH		■		*Eriogonum fasciculatum v. polifollium*
RM	WM	PQ	SB	RT		SH		■	●	*Eriogonum inflatum*
				RT					●	*Eriogonum maculatum*
			SB	RT					●	*Eriogonum palmerianum*
		PQ							●	*Eriogonum polycladon*
	WM			RT						*Eriogonum thomasii*

RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Lycium berlandieri v. longistylum*
			SB	RT				■	●	*Lycium exsertum*
			SB	RT				■	●	*Lycium fremontii*
	WM							■		*Lycium parishii*
RM	WM	PQ	SB	RT	RH	SH		■	●	*Nicotiana oblongifolia*
				RT					●	*Physalis acutifolius*
	WM		SB	RT	RH	SH	MH	■	●	*Physalis crassifolia*
		PQ						■	●	*Physalis lobata*
RM	WM		SB			SH			●	*Solanum eleagnifolium*
				RT				■	●	*Solanum nigrescens*
										Sterculiaceae
	WM	PQ	SB	RT		SH		■	●	*Ayenia compacta*
RM	WM		SB	RT		SH		■	●	*Ayenia microphylla*
				RT						*Waltheria indica*
										Tamaricaceae
			SB						●	*Tamarix pentandra*
	WM		SB					■	●	*Tamarix ramosissima*
										Ulmaceae
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Celtis pallida*
										Urticaceae
RM	WM	PQ		RT	RH	SH		■	●	*Parietaria hespera*
										Verbenaceae
RM	WM	PQ	SB	RT		SH		■	●	*Aloysia wrightii*
				RT				■	●	*Glandularia gooddingii*
	WM								●	*Tetraclea coulteri*
		PQ								*Verbena bracteata*
	WM		SB	RT				■	●	*Verbena neomexicana*
										Violaceae
	WM								●	*Hybanthus verticillatus*
										Viscaceae
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Phorodendron californicum*
										Zygophyllaceae
	WM							■	●	*Fagonia californica v. longipes*
	WM		SB	RT		SH		■	●	*Kallstroemia californica*
			SB	RT		SH		■	●	*Kallstroemia grandiflora*
RM	WM	PQ	SB	RT	RH	SH	MH	■	●	*Larrea divaricata ssp. tridentata*



Appendix III

WILDFLOWER DISTRIBUTION

SILVERBELL, WATERMAN AND ROSKRUGE MOUNTAINS

Pima County, Arizona

SILVERBELL MOUNTAINS
Vegetative Cross-section

Sonoran Desertscrub
Arizona Upland subdivision

Southerly slopes; rocky, but with enough soil development to support fairly dense vegetation. Dominants are foothill palo verde (Cercidium microphyllum), triangleleaf bursage (Ambrosia deltoidea), brittlebush (Encelia farinosa), jojoba (Simmondsia chinensis), saguaro (Carnegiea gigantea), and a variety of other cacti.

Northerly slopes, from middle elevations to the bajada; rocky, with bedrock exposed, but without the large cliffs found in the Waterman Mountains and on Ragged Top. Dominants are velvet mesquite (Prosopis velutina), catclaw acacia (Acacia greggii), whitethorn acacia (Acacia constricta), jojoba (Simmondsia chinensis), desert hackberry (Celtis pallida), ratany (Krameria spp.), and wolfberry (Lycium spp.), with stable soils covered in spike moss (Selaginella arizonica).

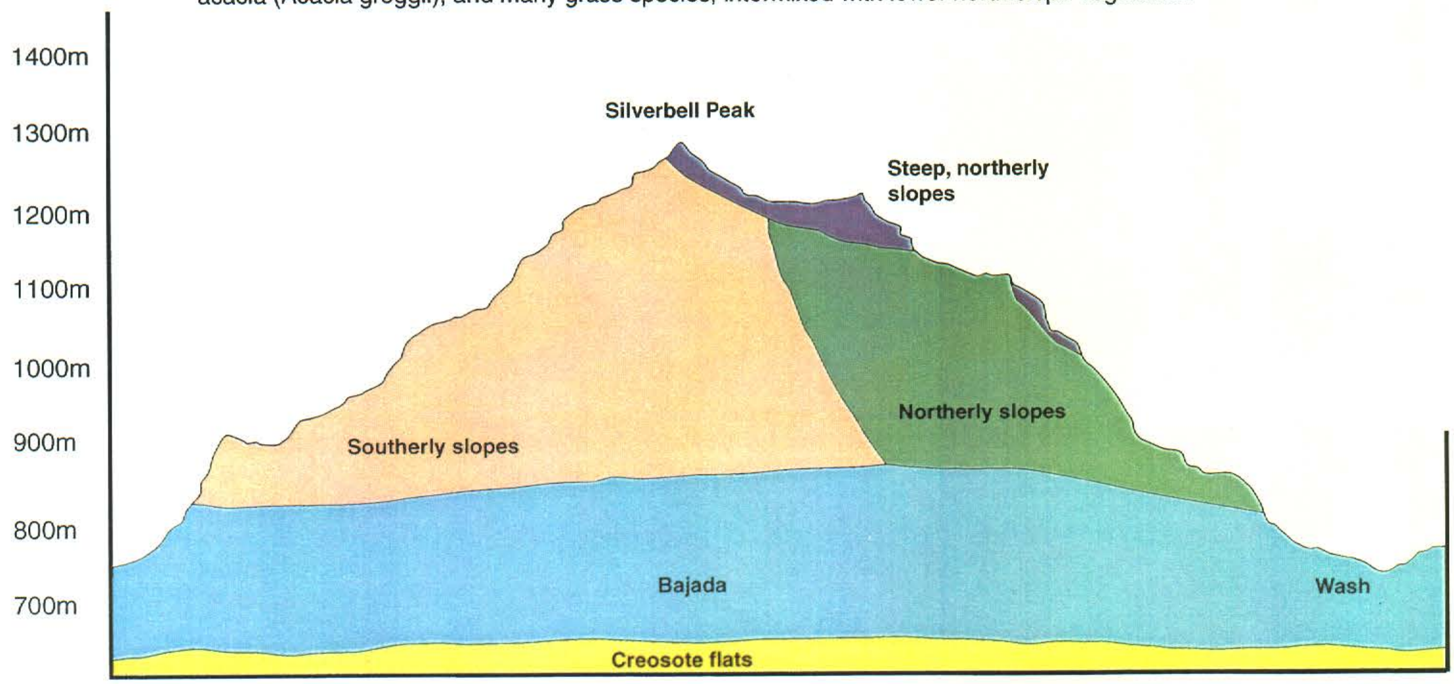
Baiadas; dominants are foothill palo verde (Cercidium microphyllum), desert ironwood (Olneya tesota), whitethorn acacia (Acacia constricts), creosote bush (Larrea divaricata), and triangleleaf bursage (Ambrosia dettoidea), with saguaro (Carnegiea gigantea) and other cacti quite common.

Washes; dominants are velvet mesquite (Prosopis velutina), catclaw acacia (Acacia greggii), whitethorn acacia (Acacia constricta), desert ironwood (Olneya tesota), desert hackberry (Celtis pallida), blue palo verde (Cercidium floridum), and canyon ragweed (Ambrosia ambrosioides).

Lower Colorado River subdivision
Creosote flats; areas below the bajada, usually with finer-grained soils. Dominants in the washes are foothill palo verde (Cercidium microphyllum), whitethorn acacia (Acacia constricta), and desert hackberry (Celtis pallida), with occasional desert ironwood (Olneya tesota). The knolls between drainages are usually restricted to creosote (Larrea divaricata), with some white bursage (Ambrosia dumosa) or triangleleaf bursage (Ambrosia deltoidea).

Semidesert Grassland and Interior Chaparral
influences in Arizona Upland Sonoran Desertscrub

Steep, northerly slopes, with small rock outcrops, have modest soil development. Here, in contrast to the Waterman Mountains and Ragged Top, grassland and chaparral vegetative elements mix with the Arizona Upland desertscrub in large areas, creating odd assemblages. Dominants are Arizona yucca (Yucca arizonica), Mormon tea (Ephedra nevadensis), white sage (Artemisia ludoviciana), Wright's buckwheat (Eriogonum wrightii), desert olive (Forestiera shrevei), turpentine bush (Ericameria laricifolia), catclaw acacia (Acacia greggii), and many grass species, intermixed with lower north slope vegetation.



RAGGEDTOP
Vegetative Cross-section

Sonoran Desertscrub
Arizona Upland subdivision

Steep, southerly, cliffs, canyons, and slopes; mostly fractured bedrock, with unstable talus slopes with poor soil development and sparse vegetation; the exception being in drainages and at the base of cliffs. Dominants are foothill palo verde (Cercidium microphyllum), brittlebush (Encelia farinosa), wolfberry (Lycium berlandieri), catclaw acacia (Acacia greggii), teddybear cholla (Opuntia bigelovii), and chuparosa (Justicia californica), with scattered oddities like bee balm (Monardella arizonica), betony (Stachs coccinea), and the semitropical plumbago (Plumbago scandens), and Waltheria incana.

Bajadas; usually around 10' of alluvium over bedrock. Dominants are foothill palo verde (Cercidium microphyllum), desert ironwood (Olneya tesota), wolfberry (Lyciu berlanderi), whitethorn acacia (Acacia constricta), triangleleaf bursage (Ambrosia deltoidea) ratany (Krameria spp.), jojoba (Simmondsia chinensis), saguaro (Carnegiea gigantea), and a variety of other cacti.

Washes; dominants are foothill palo verde (Cercidium icrophyllum), desert ironwood (Olneya tesota), whitethorn acacia (Acacia constricta), catclaw acacia (Acacia greggii), and desert hackberry (Celtis pallida). The large wash draining the southwestern watershed supports wet-canyon species such as toadrush (Juncus bufonius), deergrass (Muhlenbergia rigens), and monkey flower (Mimulus spp.). In deeper soils of washes on the lower bajada blue palo verde (Cercidium floridum) and canyon ragweed (Ambrosia ambrosioides) can be abundant.

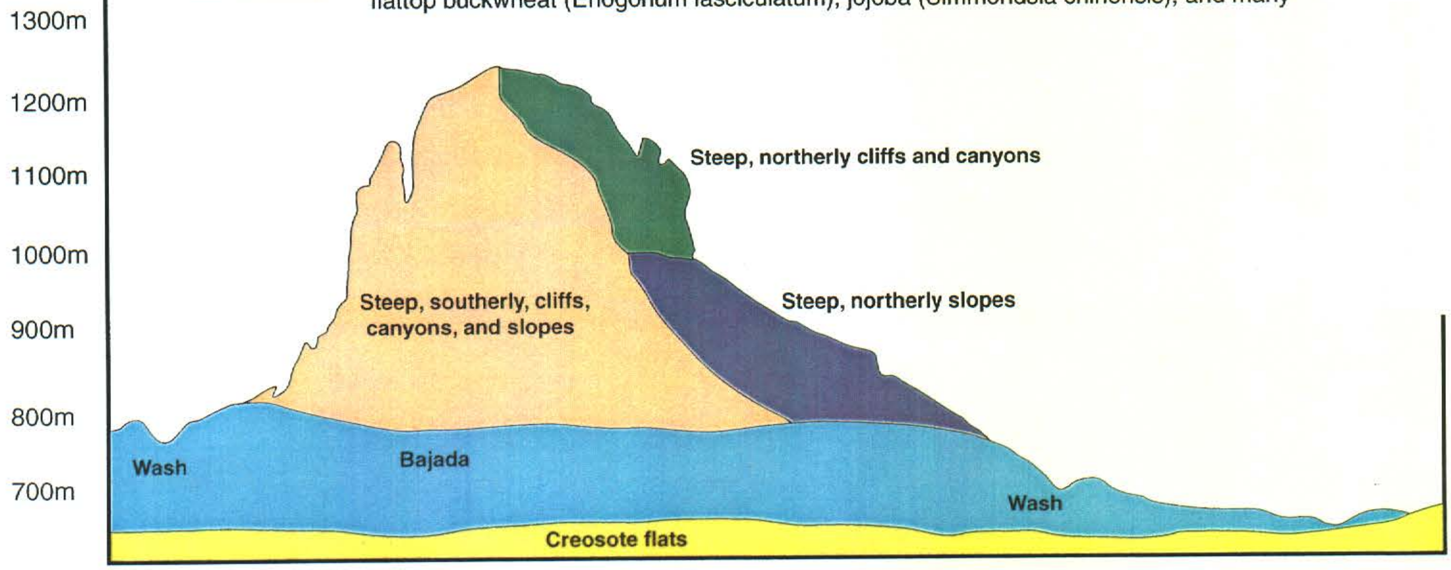
Lower Colorado River subdivision

Creosote flats; areas below the bajada, usually with finer-grained soils. Dominants in the washes here are foothill palo verde (Cercidium microphyllum), cheesebush (Hymenoclea salsola), desert ironwood (Olneya tesota), whitethorn acacia (Acacia constricta), and desert hackberry (Celtis pallida), with occasional blue palo verde (Cercidium floridum). The knolls between drainages are usually restricted to creosote (Larrea divaricata), with some desert zinnia (Zinnia acerosa), white bursage (Ambrosia dumosa), and triangleleaf bursage (Ambrosia deltoidea).

Semidesert Grassland and Interior Chaparral influences
in Arizona Upland Sonoran Desertscrub

Steep, northerly cliffs and canyons; dominants are Arizona rosewood (Vauquelina californica), catclaw acacia (Acacia greggii), turpentine bush (Ericameria laricifolia), desert olive (Forestiera shrevei), and Wright's buckwheat (Eriogonum wrightii), with scattered plants of shrub live oak (Quercus turbinella) and Arizona yucca (Yucca arizonica).

Steep, northerly slopes; precipitous, but stabilized by spike moss (Selaginella arizonica). Dominants are catclaw acacia (Acacia greggii), turpentine bush (Ericameria laricifolia), flattop buckwheat (Eriogonum fasciculatum), jojoba (Simmondsia chinensis), and many



WATERMAN MOUNTAINS
Vegetative Cross-section

Sonoran Desertscrub
Arizona Upland subdivision

Northerly slopes; dominants are foothill palo verde (Cercidium microphyllum), wolfberry(Lycium berlandieri), triangleleaf bursage (Ambrosia deltoidea), catclaw acacia (Acacia greggii), desert vine (Janusia gracilis), and trixis (Trixis californica), with scattered desert agave (Agave deserti) and turpentine bush (Ericameria laricifolia).

Southerly slopes; rocky with poor soil development and sparse vegetation; dominants are brittle bush (Encelia farinosa), foothill palo verde (Cercidium microphyllum), and wolfberry (Lycium berlandieri), with elephant tree (Bursera microphylia).

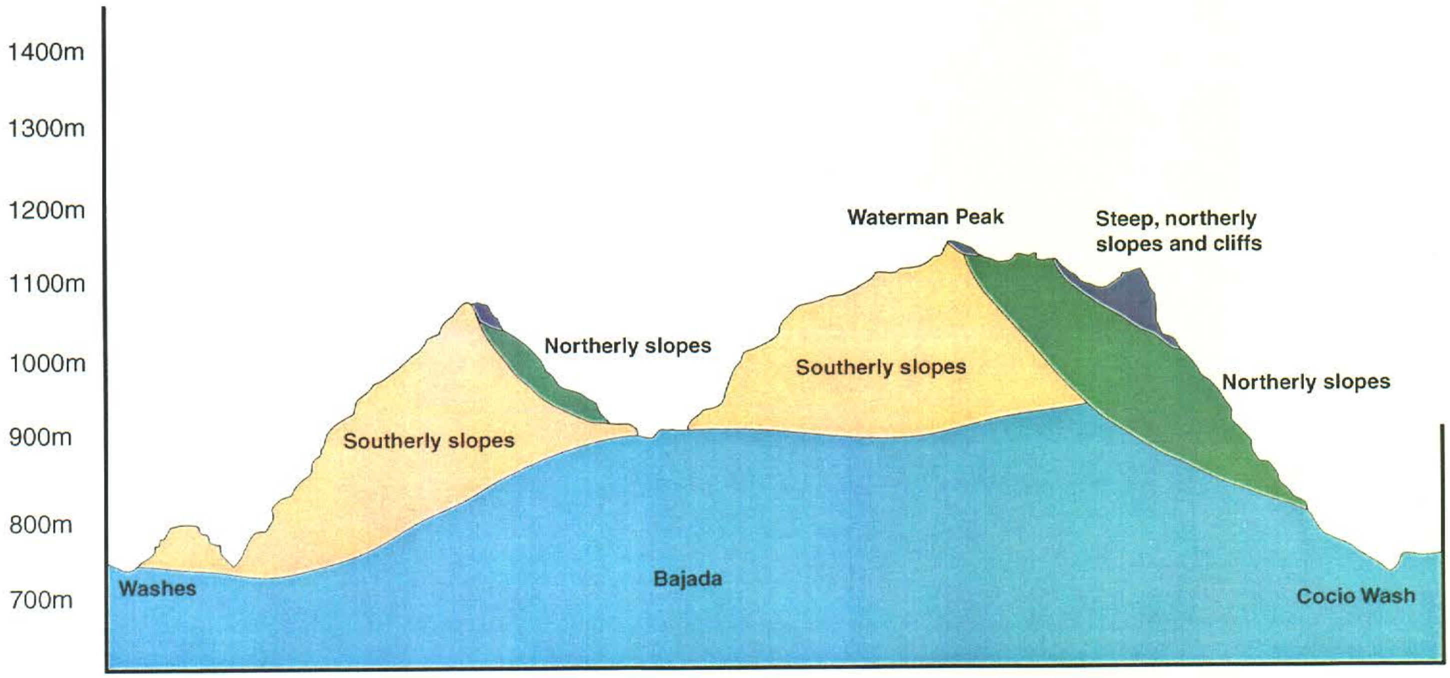
Baiadas; dominants are foothill palo verde (Cercidiu microphyllum), saguaro (Carnegiea gigantea), creosote bush (Larrea divaricata), and triangleleaf bursage (Ambrosia deltoidea), with limestone specific species such as Turk's head barrel (Echinocactus horizonihalonius var. nicholii), mariola (Parthenium incanum), and shrubby coldenia (Tiquilia caneseens). Desert ironwood is scattered here, but can be common near washes.

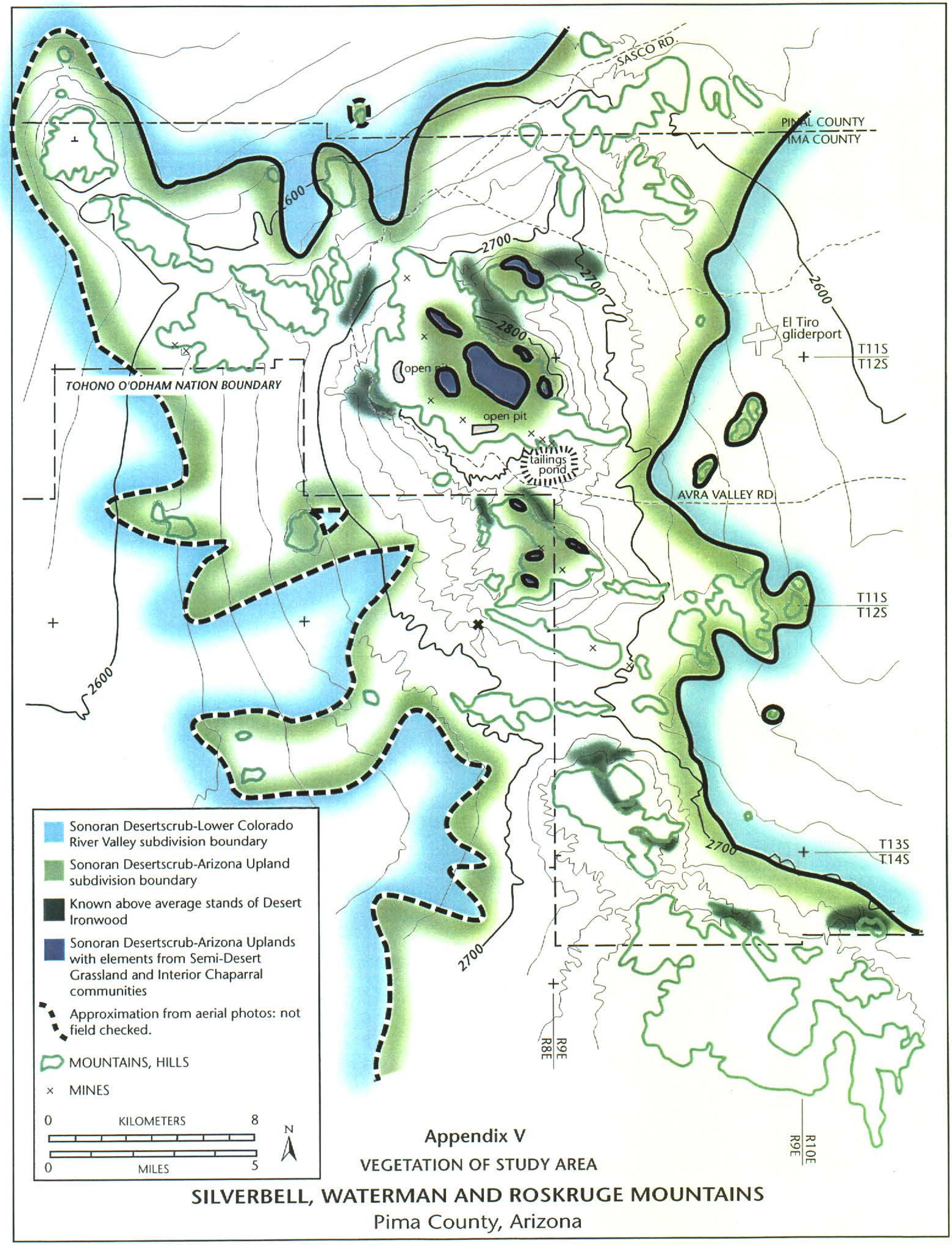
Washes; dominants are foothill palo verde (Cercidium microphyllu) desert hackberry (Celtis pallida), whitethorn acacia (Acacia constricts), and desert ironwood (Olneya tesota). In deeper soils blue palo verde (Cercidium floridum) and canyon ragweed (Ambrosia ambrosioides) can be found.

Lower Colorado River subdivision
Not shown on the diagram, but found where the lower bajada levels off. Dominants are creosote (Larrea divaricata) and bursage (Ambrosia spp.), with foothill palo verde (Cercidium microphyllum) and whitethorn acacia (Acacia constricts) in the washes.

Semidesert Grassland & Interior Chaparral influences in Arizona Upland Sonoran Desertscrub

Steep, northerly slopes and cliffs; some soil development and enhanced vegetation due to rainfall runoff from rock. Still, there is no developed grassland or chaparral vegetation type, with elements sparsely scattered among Arizona Upland species. Representatives from these biomes are Mormon tea (Ephedra nevadensis), turpentine bush (Ericameria laricifolia), and raised grass species, with a few Arizona rosewood





Appendix V

VEGETATION OF STUDY AREA

SILVERBELL, WATERMAN AND ROSKRUGE MOUNTAINS

Pima County, Arizona

Appendix VI
A List of Nocturnal Rodents on Silverbell Peak
Source: Hoagstrom, Carl W. (1978)

Chaetodipus baileyi baileyi (Bailey's pocket mouse)
Chaetodipus intermedius intermedius (rock pocket mouse)
Chaetodipus penicillatus pricei (desert pocket mouse)
Dipodomys merriami merriami (Merriam's kangaroo rat)
Mus musculus (house mouse)
Neotoma albigula albigula (white throated woodrat)
Onycomys torridus (southern grasshopper mouse)
Perognathus amplus taylory (Arizona pocket mouse)
Peromyscus eremicus eremicus (cactus mouse)
Peromyscus maniculatus (deer mouse)
Peromyscus merriami (Merriam's mouse)
Reithrodontomys megalotis (western harvest mouse)
Sigmodon arizonae (Arizona cotton rat)

Appendix VII

List of Birds recorded in the Silverbell area
IBP studies Silverbell Site 1971-1973 (20 ha plot)
(A3URJ14)

American Kestrel
Ash-throated Flycatcher
Black-tailed Gnatcatcher
Black-throated Sparrow
Brewer's Sparrow
Brown-crested Flycatcher
Brown-headed Cowbird
Bullock's Oriole
Cactus Wren
Canyon Towhee
Canyon Wren
Costa's Hummingbird
Curve-billed Thrasher
Elf Owl
Empidonax (sp.) flycatcher
Gambel's Quail
Gila Woodpecker
Gilded Flicker
Gray Vireo
Greater Roadrunner
Great-horned Owl
Green-tailed Towhee
Harris' Hawk
Hooded Oriole
House Finch
House Wren
Hummingbird (species ?)
Ladder-backed Woodpecker
Lesser Nighthawk
Lincoln's Sparrow
Loggerhead Shrike
Lucy's Warbler
MacGillivray's Warbler
Mourning Dove
Northern Cardinal
Northern Flicker
Northern Mockingbird
Orange-crowned Warbler
Phainopepla
Poorwill

Purple Martin
Pyrrhuloxia
Ruby-crowned Kinglet
Rufous-winged Sparrow
Scott's Oriole
Spotted Towhee
Starling
Violet-green Swallow
Virginia Warbler
Verdin
Western Bluebird
Western Screech Owl
White-crowned Sparrow
White-winged Dove
Wilson Warbler
Yellow-rumped Warbler