Petition to List

Tetraneuris verdiensis

as Threatened or Endangered,

with Critical Habitat,

under the Endangered Species Act

March 11, 2016

Petitioner:

Glenn Rink, 928-220-1478
801 West Birch
Flagstaff, AZ 86001
928-779-5820
Owner, Far Out Botany
Affiliate, Northern Arizona University

REQUESTED ACTION

Petitioner requests that the USFWS list *Tetraneuris verdiensis* as Threatened or Endangered.

THE CASE FOR LISTING

This Petition relies heavily on Godec's (2001) report, included with this petition.

Tetraneuris verdiensis R.A. Denham & B.L. Turner (Verde four-nerve daisy) is a narrowly endemic, edaphic, perennial plant in the sunflower family. It is endemic to the Verde Valley on lands managed by the Coconino National Forest. Its entire known range is 10,790 m^2, only growing on low gypsum mesas near an active gypsum mine. Approximate population size in the year 2000 was 3298 individuals (Godec 2001). Nature Serve presently considers *Tetraneuris verdiensis* to be G1, N1, S1 (explorer.natureserve.org accessed online Dec.27, 2015).

The type locality for *Tetraneuris verdiensis* is on the top of a low mesa of a gypsum stratum of the Late Tertiary Verde Formation. Additional populations occur on the tops of three adjacent small mesas within this stratigraphic unit (Figure 1). Godec (2001) surveyed all suitable and similar habitats within a 3-mile radius of the type locality, finding *Tetraneuris verdiensis* only on the four mesas associated with the type locality. This habitat consists of the tops of low chalky mesas composed of gypsum crystals, gravel, and marl, occupied by a dwarf sub-shrub community of numerous perennial species.

This small group of gypsiferous mesas also supports other edaphic species, such as *Eriogonum ericifolium* Torrey & A. Gray var. *ericifolium* (G3, T2, N2, Forest Service Sensitive), *Salvia dorrii* (Kell.) Abrams subsp. *mearnsii* (G5, T3, N3, Forest Service Sensitive), and *Lesquerella cinerea* S. Wats. (USFS Protection of these mesas would not only benefit *T. verdiensis*, but would also benefit these other rare edaphic endemic species.

TAXONOMY

Tetraneuris verdiensis was first published in 1996 (Denham and Turner). *Tetraneuris verdiensis* populations are consistently discoid (with no ray flowers) and occur on gypsiferous soil. Its close relative, *Tetraneuris acaulis* (Pursh) Greene var. *arizonica* (Greene) K. L. Parker, consistently has ray flowers and occurs on limestone and sandstone soil, and occurs about seven miles distant, within the Verde Valley. *Tetraneuris acaulis* var. *arizonica* is probably the most closely related taxon to *T. verdiensis* and is common in northern Arizona and southern Utah, but

is uncommon in the Verde Valley, where it is documented along Middle Verde Road (*Anderson 95-17* ASU). These two taxa have not been documented occurring together.

The most important characteristic distinguishing these two species is the consistently discoid flower heads of *Tetraneuris verdiensis*. Denham and Turner (1996) also stated that *T. verdiensis* differs from *T. acaulis* var. *arizonica* in its dwarf habit, long pilose vestiture, and relatively short broad leaves. A population of *T. acaulis* var. *arizonica* in the Verde Valley does exhibit a dwarf habit, long pilose vestiture, and relatively short broad leaves. Although the hairs in this population of *T. acaulis* var. *arizonica* are not as abundant as in *T. verdiensis*, the characters that these plants exhibit appear to provide evidence of intergradation and intermediate forms between the two taxa. Uncommon discoid individuals of *T. acaulis* var. *arizonica* have been noted in Verde Valley populations where the dominant form has ray flowers.

Discoid individuals have been documented in Wyoming populations of *Tetraneuris acaulis* Greene var. *acaulis*. These rayless individuals are isolated and only differed from the typical form of this species in their rayless condition. Those plants were the basis of *T. eradiata* A. Nelson, but are currently considered to be deviant forms of *T. acaulis* var. *acaulis* (Denham and Turner 1996).

Consideration of taxonomic validity is critical to discussions about rare plants, discussions which often become contentious and, of course, entail personal bias. At some point, without molecular evidence, it comes down to a consensus among knowledgeable experts. Here is what Bierner has to say about *T. verdiensis*, "I do believe that *Tetraneuris verdiensis* is a legitimate taxon. For one thing, it is a true gypsophile, and for another it is always discoid. There are no other gypsophilic taxa in *Tetraneuris* (that I can think of), and the only other consistently discoid taxon in *Tetraneuris* is *Tetraneuris argentea* (A. Gray) Greene var. *thoreauensis* (N. D. Atwood, S. L. Welsh & A. Clifford) Bierner & B. L. Turner found in northwestern New Mexico (on limestone derived soil)." (email correspondence, June 8, 2015). John Anderson, retired BLM botanist for Arizona, who did his MS work on plant species endemic to the inland lake deposits in Arizona, believes that *Tetraneuris verdiensis* is neither a valid species nor variety and that protective agencies like the USFWS "has much more taxonomically distinct rare species to work on that would take precedent of their time over this one." (email correspondence, December 17, 2015).

DISTRIBUTION and POPULATION

Despite two targeted searches made in the area, no other populations of *Tetraneuris verdiensis* have been located.

Godec (2001) searched 18 low hills and mesas in the nearby area for the presence of this species, based on soil characteristics and the presence of similar vegetation. Each of these areas contained sub-shrub communities with many of the same species found at the type location. Of the 18 study areas, only 10 appeared to contain the same mix of gypsum, marl, and gravel substrates as the type location. The unique gypsiferous soils of the type location are limited to the southeastern portion of the Verde Valley, where the deepest portions of the ancient lake were located. *Tetraneuris verdiensis* was found only on the tops of four low mesas: the type location and three low mesas adjacent to it (Figure 1). It is possible that more populations are present that were not detected during Godec's survey. The distribution was patchy, and primarily limited to the tops of the mesas or on gently sloping areas at the mesa margins. Steeper sides of these mesas, and areas at the base of these mesas with very similar soils and sub-shrub communities, lacked this species. Also, this species was not found on these mesa tops where thicker shrub communities and more gravelly or cobbly soils were present.

This taxon occurred in seven distinct population segments on these four low mesas. Godec (2001) estimated the number of plants present in each of these population segments, and sampled the entire population with 18, 5 m wide transects of variable length. Godec determined the average number of plants per square meter for these transects, and derived a population estimate based on the total area covered by the population segment and the total number of plants per square meter in the sampled transects. Godec estimated that there were approximately 3,298 plants present on these four mesas, while noting that the exact number of plants is difficult to determine with this species, as multiple above ground stems are commonly associated with one plant. Godec estimated that the total area occupied by this species was 10,790 m^2 (1.08 hectares). By far, the largest population is at the type location, where Godec estimated 1,808 plants.

Murray (2008) repeated surveys of surrounding mesas and hills during 2007/8 with similar results, not finding any *Tetraneuris verdiensis* outside of the previously documented areas. As part of her work, Murray installed three permanent monitoring plots and mapped the known populations (Figure 3).

REGULATORY PROTECTIONS

Currently, there are no regulatory protections in place, nor that have been initiated, to protect this species or its habitat. Talks have been initiated between the Coconino National Forest botanist (Deb Crisp), the lands specialist at the Coconino National Forest ( ), a tribal liaison with the USFWS John Nystedt, and the tribe, but these talks have not resulted in any agreements, or even any progress toward an agreement to protect the habitat where *Tetraneuris verdiensis* occurs.

THREATS

All known occurrences of *Tetraneuris verdiensis* are located on land managed by the Coconino National Forest. Two significant threats to this plant's continued existence are:

1) OHV use of the area, and

2) expansion of an existing gypsum mine

Figure 1 is a close Google Earth view of the area where *Tetraneuris verdiensis* grows, showing OHV use. The degree of OHV disturbance directly on *Tetraneuris verdiensis* occupied habitat is presently minimal; however, nearby damage caused by OHVs includes erosion, uprooting impacted plants, and soil compaction (Murray 2008). Similar OHV use within *T. verdiensis* occupied habitat would be a significant threat to this plant.

Tribally owned land directly south of the mesas occupied by *Tetraneuris verdiensis* is presently being mined for gypsum by the Salt River Tribe. Portions (or all; research needed) of the land that is occupied by *Tetraneuris verdiensis* is claimed for mining activity by the Salt River Tribe, who according to Judy Adams of the Coconino National Forest lands staff, have indicated that their claim activity is designed to maintain their rights; and that they have no immediate plans to mine the sites on USFS lands (Crisp, pers comm). Mining is an accepted legitimate use of USFS lands; however, mining development on these mesas would probably invoke the NEPA process.

A Google Earth view (Figure 2) reveals the mining activity to the west and southwest (north is up) of the four low mesas (light-colored mesas at the upper right outlined in red) that host the only known populations of *Tetraneuris verdiensis*. The most likely direction to expand mining activity from this mine is to the north and east, where gypsum exists under *Tetraneuris verdiensis* habitat.

Because of threatened mining activity and potential OHV use, *Tetraneuris verdiensis* meets the criteria of Part 424—Listing Endangered and Threatened Species and Designating Critical Habitat § 424.11 (1) The present or threatened destruction, modification, or curtailment of its habitat or range; (2) Over utilization for commercial, recreational, scientific, or educational purposes.

CONCLUSIONS

Tetraneuris verdiensis has a severely limited range and very specific habitat requirements. Of 18 hills and mesas searched during two separate surveys, this species was documented only on the tops of four adjacent mesas in the Verde Valley, occurring in seven distinct subpopulations. The

estimated population of 3,298 plants, covering approximately 10,790 sq m (1.08 hectares) means that mining disturbance could easily eliminate the taxon, and OHV use could severely impact it.

Both mining and OHV use are allowed on USFS lands, though the NEPA process might be invoked prior to any mining development.

Protection of these mesas would not only benefit *Tetraneuris verdiensis*, but would also benefit two other edaphic endemic species (*Eriogonum ericifolium* var. *ericifolium* (AZ S2, CNF sensitive) and *Salvia dorrii* subsp. *mearnsii*, (AZ S3, CNF sensitive) that occur on these same low mesas. Further investigations into the distribution of this plant within the Verde Valley may uncover new populations.

PROPOSED DESIGNATED CRITICAL HABITAT

Designation of Critical Habitat should include all of the area presently known to host these plants, four mesas at the southeastern end of the Verde Valley, and includes a total of about 1 hectare. The tops and upper slopes of these four mesas provide the unique gypsiferous soils and associated species that collectively enable the survival of this species. A first approximation of the outside bounding points of this area, starting at the north and working clockwise are: 34° 32' 40.05", 111° 46' 25.60"; 34° 32' 31.54", 111° 46' 18.49"; 34° 32' 19.73", 111° 46' 25.14"; 34° 32' 16.37", 111° 46' 45.57"; 34° 32' 20.55", 111° 46' 45.82".

LITERATURE CITED

All attached with this proposal

Crisp, Debbie. 2015. Field Visit to *Tetraneuris verdiensis* location. Unpublished internal Coconino National Forest report, Flagstaff, AZ.

Denham, R. A., and B. L. Turner. 1996. A new species of *Tetraneuris* (Asteraceae, Helenieae) from the Late Tertiary Verde Formation of central Arizona. Phytologia 81(1):5-9.

Godec, Daniel J., 2001. Distribution and taxonomic discussion of *Tetraneuris verdiensis*, an apparently rare edaphic endemic from the Verde Valley of Arizona. *in* Maschinski, J. and L. Holter. Tech. eds. Southwestern rare and endangered plants: Proceedings of the Third conference; 2000 September 25-28; Flagstaff, AZ. P.238-246.Proceedings RMRS-P-23. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Murray, Sheila. 2008. Final Report, Distribution and status of the recently described *Tetraneuris verdiensis* in the Verde Valley, Arizona, USA, The Arboretum at Flagstaff.

USFS. nd. Forest Service Sensitive Species that are not listed or proposed under the ESA, accessed online 11-Mar-2016 at http://www.fs.fed.us/biology/resources/pubs/tes/fs_ss_310ct05.pdf.

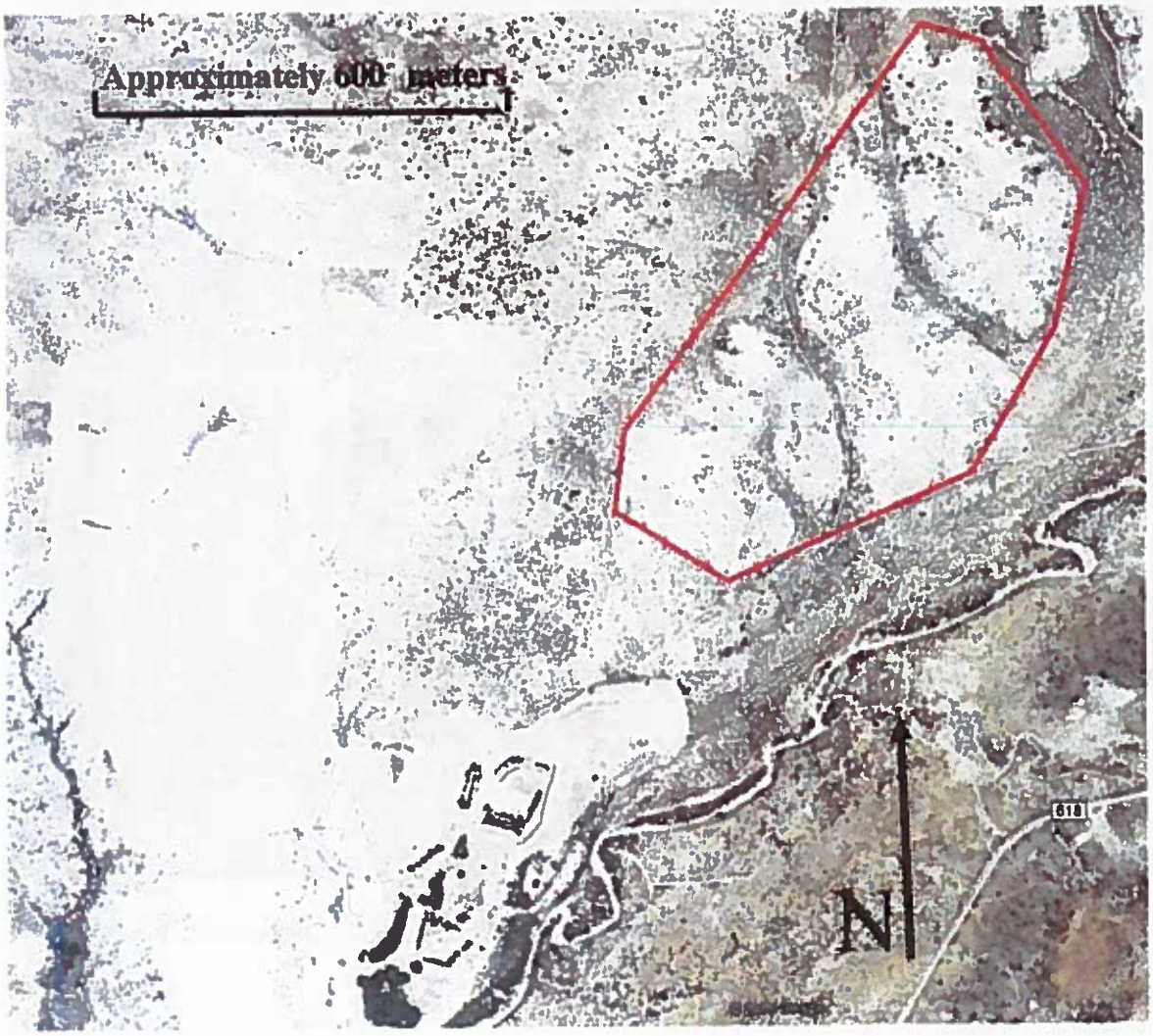

Figure 1. The location of the four low gypsum mesas is outlined in red. Operating gypsum mine to the south and west. Forest Road 618 in the southeast corner.

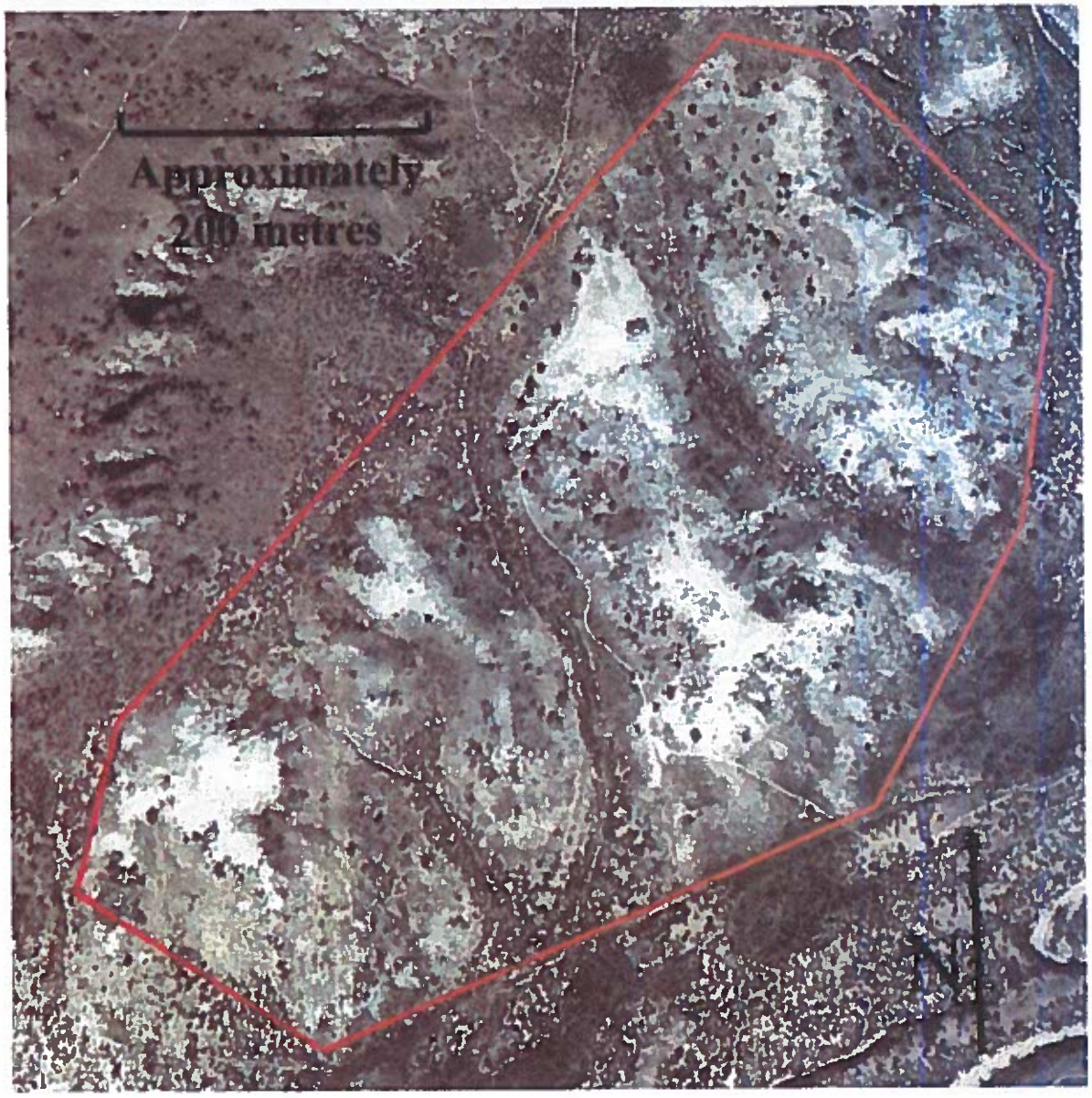

Figure 2, Detail of the extent of OHV use in the area of *Tetraneuris verdiensis*, use that is unrestricted at this point in time.

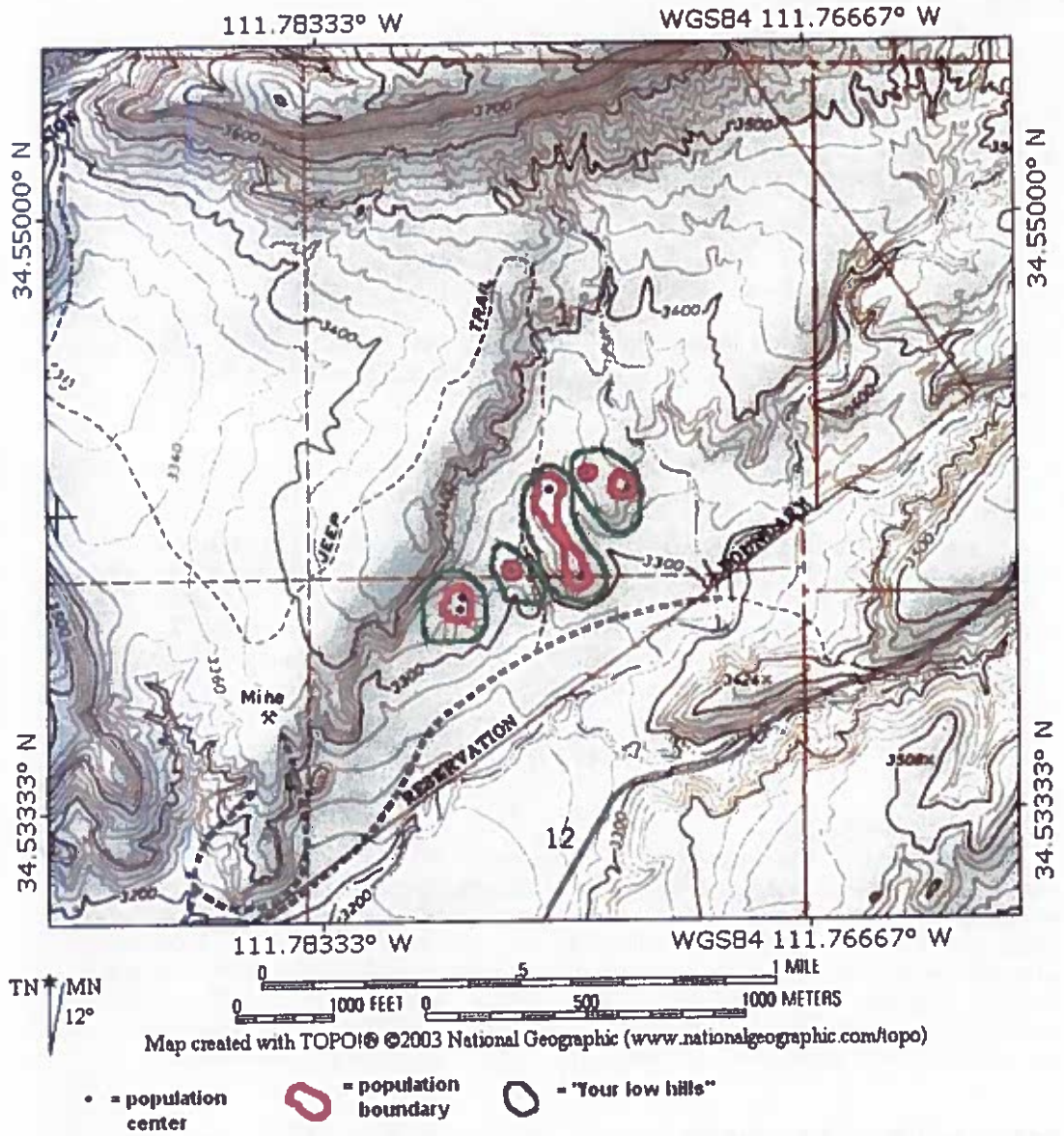

Figure 3, Murray's (2008) map delineates both the four low mesas where *Tetraneuris verdiensis* populations and more precisely where those populations are located.

Phytologia (July 1996) 81(1):5-9

A NEW SPECIES OF *TETRANEURIS* (ASTERACEAE, HELENIEAE) FROM THE LATE TERTIARY VERDE FORMATION OF CENTRAL ARIZONA

Robert A. Denham[1] & B. L. Turner[2]

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ABSTRACT

A new species, ***Tetraneuris verdiensis*** R.A. Denham & B.L. Turner, is described from Yavapai County, Arizona where it is restricted to lacustrine marl in the Verde Formation. It is related to the *Tetraneuris "scaposa -- acaulis* complex," and can be readily distinguished from the closely sympatric *T. scaposa* (*Hymenoxys acaulis* var. *arizonica*) by its dwarf habit, relatively short broad leaves, long-pilose vesuture, and rayless heads.

KEY WORDS: Asteraceae, Helenieae, *Tetraneuris*, Arizona

Preparation of a systematic study of the genus *Tetraneuris* (Bierner & Turner 1997) by the junior author has occasioned the present paper. This new species was brought to his attention by the senior author, who first became aware of its existence during the winter of 1993-1994 while engaged in floristic studies of localized substrates within the lacustrine limestone Verde Formation in northeastern Yavapai County, Arizona. Jean Searle of the Arizona Native Plant Society, while accompanying the senior author on a field trip to the type location, first pointed out the uniqueness of these populations as compared to *Tetraneuris* elsewhere in Arizona.

TETRANEURIS VERDIENSIS R.A. Denham & B.L. Turner, *spec. nov.* TYPE: U.S.A. Arizona: Yavapai Co., 5 mi. E of Camp Verde, 3300 ft., occurring on marl with gypsum crystals at the surface, 14 May 1995, *Denham, Fobes, & Searle 1840* (HOLOTYPE: TEX).

Similis *Tetraneuri scaposae* (DC.) Greene sed planta nana et eradiata est, 4-7 cm alta, indumentum candudum -- pilosum habens, pilis 3-7 mm longus.

Dwarf scapose perennial 4-7 cm high, the stems arising from a branched woody caudex. Leaves relatively thick, all basal, 1.5-2.5 cm long, 3-5 mm wide, blades ovate to narrowly ovate, moderately but deeply glandular-punctate, entire, markedly

white-pilose throughout with hairs 3-6 mm long, the apices acute to obtuse. Scapes 4-6 cm long, ebracteate, pilose with upwardly appressed and widely spreading hairs 1-4 mm long. Heads single, hemispheric. Involucres 5-6 mm high, 3-4 mm across. Ray florets absent. Disk florets ca. 40 (est.); corollas yellow, ca. 3.5 mm long, the tube ca. 0.5 mm long, the lobes 5, densely pubescent. Anthers yellow with ovate appendages. Style branches truncate, apically hispidulous. Achenes (immature) ca. 3 mm long, densely pubescent; pappus of ca. 8 lanceolate scales 2-3 mm long.

Additional collections: *Denham, Fobes, & Searle 1835, 1836, 1837, 1838,* and *1839,* all from the same location as the type, from either the same population as the type or from an adjacent population on a nearby hilltop.

GEOLOGY AND FLORISTICS OF THE TYPE LOCATION

Tetraneuris verdiensis can best be understood with a perspective on the geology and floristic patterns of the type location and surrounding areas within the Verde Formation. During the late Tertiary Period, the Verde Formation and other lacustrine deposits formed in a series of basins across the sub-Mogollon region of Arizona. These basins are home to a number of endemics which are often restricted to particular substrates. In addition to these endemics, disjunct occurrences of several other species are found in these lacustrine deposits (Anderson 1996).

The Verde Formation in northeastern Yavapai County was formed primarily through deposition and precipitation within a shallow lake bed created by down-dropping along the Verde Fault and subsequent blockage of the drainage outlet by volcanic and/or tectonic activity. The upper part of the formation, exposed at the northwestern end of the Verde Valley near Cottonwood, Arizona, is comprised of narrow interbedded layers of limestones, mudstones, and marls. The lower part of the formation, exposed at the southeastern end of the valley near Camp Verde, Arizona, is comprised mostly of more massive limestones formed in the deepest parts of the lake and evaporites, such as salt deposits and gypsum. Near the lower end of the valley are volcanoclastic deposits adjacent to and of approximately the same age as the lacustrine deposits.

Major changes in the floristic communities occur along with changes in substrate within the Verde Formation. The xeric hillside habitats on the interbedded layers near the upper end of the valley are dominated by *Canotia holacantha* and *Juniperus coahuilensis* (Martinez) Gaussen *ex* R.P. Adams. On the massive limestones in the lower valley, the flora includes some species more typical of higher elevations, such as *Juniperus osteosperma* (Torrey) Little, *Purshia stansburiana* (Torrey) Henrickson, and *Ipomopsis aggregata* (Pursh) V. Grant. The adjacent volcanic tuff supports a community with a Sonoran component, including *Agave chrysantha* Peebles, *Opuntia acanthocarpa* Engelm. & Bigelow var. *thornberi* (Thornber & Bonker) L. Benson, and *Acacia constricta* Benth.

Several taxa endemic to the late Tertiary sub-Mogollon lacustrine basins are found to occur along particular soil horizons. In the Verde Valley, *Purshia subintegra*

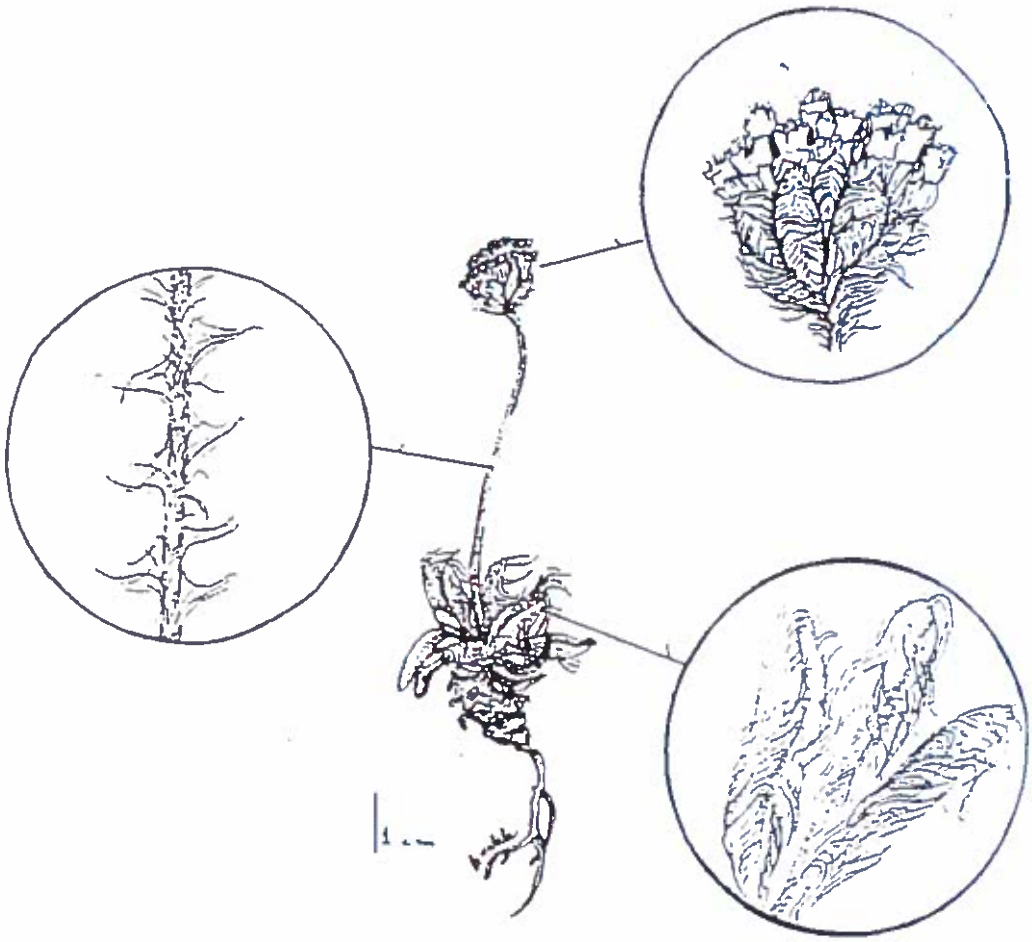


Figure 1. *Tetraneuris verdiensis* R.A. Denham & B.L. Turner, from holotype. The enlarged circle at lower right depicts several folded leaves.

(Kearney) Henrickson only occurs near the upper end of the Verde Formation and then only where there are clastic elements derived from the Mesozoic sandstones of the Supai Group, and *Eriogonum apachense* is restricted to a horizon at ca. 3500' in the block-forming limestones of the lower valley. Many other species with disjunct occurrences in the lacustrine Verde Formation also follow a similar pattern of being restricted to specific soil horizons. For example, *Quercus havardii* Rydb. var. *tuckeri* Welsh from southeastern Utah is disjunct from its nearest population by almost 170 miles, and is found in central Arizona only at locations where a particular powdery clay-like calcium carbonate soil is exposed at ca. 3400' in the vicinity of Dead Horse Ranch State Park.

In the lowest, southeastern-most end of the lacustrine deposits, several narrow bands of different soils running northeast-southwest are exposed. Within three miles, one can go from limestones, across bands of gypsum and marl, and continue onto volcanic tuff, each of these substrates accommodating their own floristic community. In this area, the type population of *Tetraneuris verdiensis* occurs on one of a series of low chalky flat-topped hills composed of marl with gypsum crystals at the surface. Additional populations of *Tetraneuris verdiensis* occur on the tops of the adjacent small hills within this stratigraphic unit.

The type location supports a dwarf sub-shrub community dominated by *Eriogonum ericifolium* Torrey & A. Gray var. *ericifolium*, an edaphic endemic known only from lacustrine deposits within the Verde Formation. Co-dominant is *Salvia dorrii* (Kell.) Abrams subsp. *mearnsii*, endemic to the Verde Formation and adjacent sandstones. Overall, the distribution of *Tetraneuris verdiensis* is consistent with the pattern of edaphic endemism found within the Verde Formation and other late Tertiary lacustrine deposits in central Arizona.

THE TAXONOMY OF *TETRANEURIS VERDIENSIS*

The genus *Tetraneuris* is known from the Great Basin, the Rocky Mountains, and the Great Plains. It reaches its southwestern limit in north-central México. *Tetraneuris scaposa* Greene (including *Hymenoxys acaulis* (Pursh) Parker var. *arizonica* [Greene] Parker) is common in the northern parts of Arizona. This taxon also has a disjunct range to the south in the lacustrine limestone Verde Formation and adjacent Mesozoic sandstones in Yavapai County (Anderson 1996 *ibid.*). In the Verde Valley, *T. scaposa* has been collected by the senior author at Cottonwood, Arizona near the upper end of the valley. Anderson (1996 and pers. comm.) has collected this same taxon along Middle Verde Rd., west of Camp Verde, Arizona. This latter site is approximately seven miles from the type location of *T. verdiensis*. Although both of these species occur in the Verde Valley, there is no evidence of intergradation, no intermediate forms, and no individuals exhibiting a recombination of characteristics between these two species.

One important characteristic of *Tetraneuris verdiensis* is its discoid heads. Discoid individuals are known elsewhere in *Tetraneuris*, as isolated individuals within populations of *T. acaulis* Greene (*Hymenoxys acaulis* var. *acaulis*) in Wyoming.

These individuals, which have formed the basis for *T. eradiata* A. Nelson, differ from their neighbors only in their discoid condition, and are currently considered to be aberrant forms of *T. acaulis*. The situation in the Verde Valley is radically different. Here *T. scaposa* and *T. verdiensis* can be distinguished by a suite of characteristics which are always consistent at the population level. In addition to its discoid heads, *T. verdiensis* differs from *T. scaposa* in its dwarf habit, relatively short broad leaves, and long pilose vestiture. Other than *T. verdiensis*, there has been no report in *Tetraneuris* of entire populations, or series of populations, which are wholly discoid.

CONCLUSION

In *Tetraneuris* and in the closely related *Hymenoxys*, a syndrome of characteristics, some of these subtle, separate the various species. The degree of morphological distinction of *Tetraneuris verdiensis* is consistent with recognition at the species level within both of these genera. In short, *Tetraneuris verdiensis* is a relatively well-marked localized edaphic endemic of central Arizona.

ACKNOWLEDGMENTS

Gayle Turner provided the Latin diagnosis, and we are grateful to Mark Bierner and Ted Delevoryas for reviewing the manuscript. We would also like to thank John L. Anderson for additional information on the distribution of *Tetraneuris scaposa* (*Hymenoxys acaulis* var. *arizonica*) in the Verde Valley, and Elizabeth Mathews, Northern Arizona Zone Geologist, United States Forest Service, for clarification of the finer points of the geology of the Verde Valley.

LITERATURE CITED

Anderson, J.L. 1996. Floristic Patterns on Late Tertiary Lacustrine Deposits in the Arizona Sonoran Desert. Madroño 43:225-272.

Bierner, M. & B.L. Turner. 1997. Systematic overview of the genus *Tetraneuris* (Asteraceae, Helenieae). in prep.

Final Report

Distribution and Status of the Recently Described *Tetraneuris verdiensis* in the Verde Valley, Arizona, USA.

Submitted by: Sheila Murray, Research Botanist, The Arboretum at Flagstaff
August 24, 2008

Objectives and Activities:

Objective 1: All available information, collections and location data will be synthesized and analyzed. Maps will be prepared and digitized for ArcView analysis. Preliminary site visits will be made to assess current threats and conditions.

Below are abstracts and references for information regarding *T. verdiensis*.

Abstract: A new species, *Tetraneuris verdiensis* R.A. Denham & B.L. Turner, is described from Yavapai County, Arizona where it is restricted to lacustrine marl in the Verde Formation. It is related to the *Tetraneuris "scaposa – acaulis* complex", and can be readily distinguished from the closely sympatric *T. scaposa* (*Hymenoxys acaulis* var. *arizonica*) by its dwarf habit, relatively short broad leaves, long-pilose vestiture, and rayless heads.

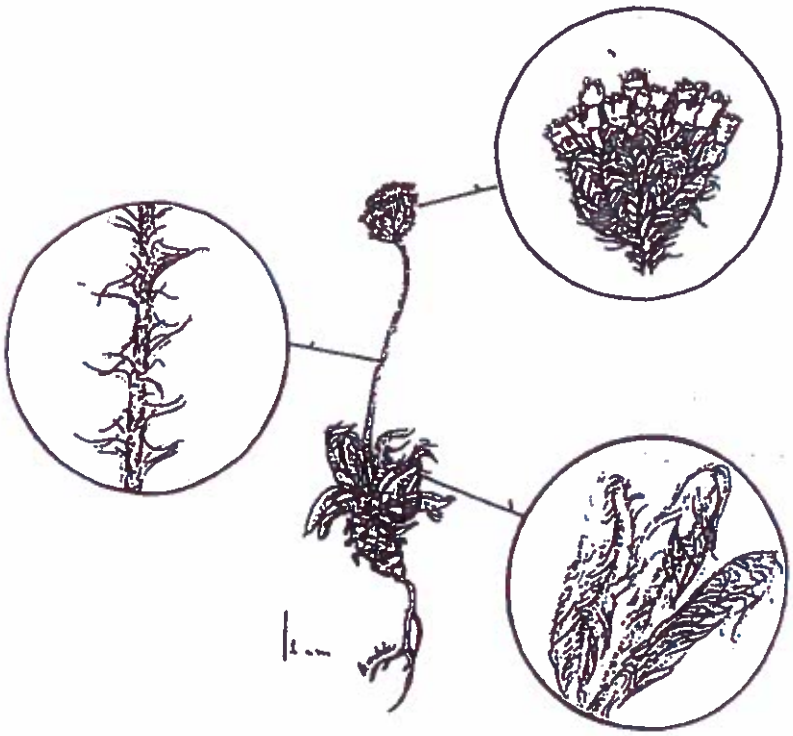


Figure 1. *Tetraneuris verdiensis* R.A. Denham & B.L. Turner, from holotype. The enlarged circle at lower right depicts several folded leaves.

Denham, R.A. and B.L. Turner. 1996. A new species of *Tetraneuris* (Asteraceae, Helenieae) from the late Tertiary Verde Formation of central Arizona. Phytologia 81(1): pp 5-9.

Abstract: *Tetraneuris* is recognized as a genus separate from *Hymenoxys* and a taxonomic treatment is presented for the 14 taxa recognized as constituting *Tetraneuris:* *T. acaulis* var. *acaulis*, *T. acaulis* var. *arizonica*, *T. acaulis* var. *caespitosa*, *T. acaulis* var. *epunctata*, *T. argentea*, *T. herbacea*, *T. ivesiana*, *T. linearifolia* var. *linearifolia*, *T. linearifolia* var. *arenicola*, *T. scaposa* var. *scaposa*, *T. scaposa* var. *argyrocaulon*, *T. torreyana*, *T. turneri*, and *T. verdiensis*. The revision includes synonymies, typifications, descriptions, discussions, and range maps for each of the accepted species.

TABLE 1. Chromosome numbers in *Tetraneuris*. All counts are given as haploid numbers regardless of whether they were reported as haploid or diploid. Only one collection or voucher is shown for each count. Vouchers examined as part of this study are cited in Representative Specimens.

Taxon	*n*	Collection or bibliographic reference
T. acaulis var. *acaulis*	14	Powell and Turner, 1963
	15, 30	Strother, 1966
	28	Johnston and Bonde, 1969 (as var. *arizonica*)
T. acaulis var. *arizonica*	14	*Windham 97-207* (UT!)
	15, 30	Strother, 1966
	28	*Windham 98-161* (UT!)
T. acaulis var. *caespitosa*	14	Johnston and Bonde, 1969
	15	*Wiens 2866* (COLO!)
T. acaulis var. *epunctata*	14	*Windham 93-143* (COLO!, UT!)
	15	*Watson 889* (MONTU!)
	28	*Windham 99-158* (UT!)
T. argentea	15, 30	Strother, 1966
T. herbacea	14	Cusick, 1991
T. ivesiana	14, 28	Johnston and Bonde, 1969
	15, 30	Strother, 1966
T. linearifolia var. *arenicola*	15	Bierner et al., 1992
T. linearifolia var. *linearifolia*	14	Strother, 1983
	15, 30	Zhao, 1996
T. scaposa var. *argyrocaulon*	15	*Strother 555* (TEX!)
T. scaposa var. *scaposa*	15, 30	Strother, 1966
T. torreyana	14	*Windham 96-140* (UT!)
T. turneri	45	Parker, 1970
T. verdiensis	Unknown	

Bierner, M.W. and B.L. Turner. 2003. Taxonomy of *Tetraneuris* (Asteraceae: Helenieae: Tetraneurinae). Lundellia 6: pp 44-96.

Abstract: *Tetraneuris verdiensis* was first published in 1996. It appears to be closely related to *Tetraneuris acaulis* var. *arizonica*. The closest known location of *T. acaulis* var. *arizonica* is approximately 7 miles northwest of the known *T. verdiensis* locations, which are 5 miles east of Camp Verde. *Tetraneuris verdiensis* is significant in that no other entirely discoid populations, or series of populations, of *Tetraneuris* have been reported. *Tetraneuris verdiensis* populations are consistently discoid, which separates them from *T. acaulis* var. *arizonica*. The type locality is on the top of a low hill of a gypsum stratum of the Late Tertiary Verde Formation. Denham and Turner (1996) stated that additional populations occur on the tops of the adjacent small hills within this stratigraphic unit. Results of a survey of all of the similar gypsum hills and mesas in this area east of Camp Verde are presented, along with population sizes for each gypsum hill where this species occurs. The morphological similarities and differences between *T. verdiensis* and *T. acaulis* var. *arizonica* are discussed, as well as the taxonomic status of *T. verdiensis*.

Godec, D.J. 2000. Distribution and Taxonomic Discussion of *Tetraneuris verdiensis*, an Apparently Rare Edaphic Endemic from the Verde Valley of Arizona. Proceedings of the Third Southwestern Rare & Endangered Plants Conference. USDA RMRS P-23. Sept 25-28, Flagstaff, Arizona. pp 238-246.

Objective 2: Surveys will be conducted in known populations, as well as in additional habitat. Counts of individuals will be made along belt transects or in macroplots of known size which will then be extrapolated to estimate numbers of plants in populations. A random sampling approach will be used, with a randomly generated series of survey points chosen. These will then be visited to determine presence/absence of the species as well as local abundance. This random sampling design will then allow inferences to overall population size.

Dan Godec (2000) conducted surveys of *Tetraneuris verdiensis* in May of 1999 and 2000. He based the suitable habitat on Denham and Turner's (1996) description. All suitable and similar habitats within a 3-mile radius of the type locality were surveyed. In total, 18 low hills and mesas in the nearby area were searched, based on soil characteristics and the presence of similar vegetation. Of the 18 study areas, only 10 appeared to contain the same mix of gypsum, marl, and gravel substrates as the type location. *T. verdiensis* was found only on the tops of four low hills: the type location and three hills adjacent to it. Distributions were patchy, and primarily limited to the tops of the hills or on gently sloping areas at the edges of the tops. Steeper sides of these hills were conspicuously lacking *T. verdiensis*. The species occurred in seven distinct population segments on the four low hills. It was estimated that the total number of plants was 3,298. The estimated total area of suitable habitat occupied by the species was 10,790 square meters. By far, the largest population was at the type location. The only insect pollinator observed was a bee fly (Family Bombyllidae).

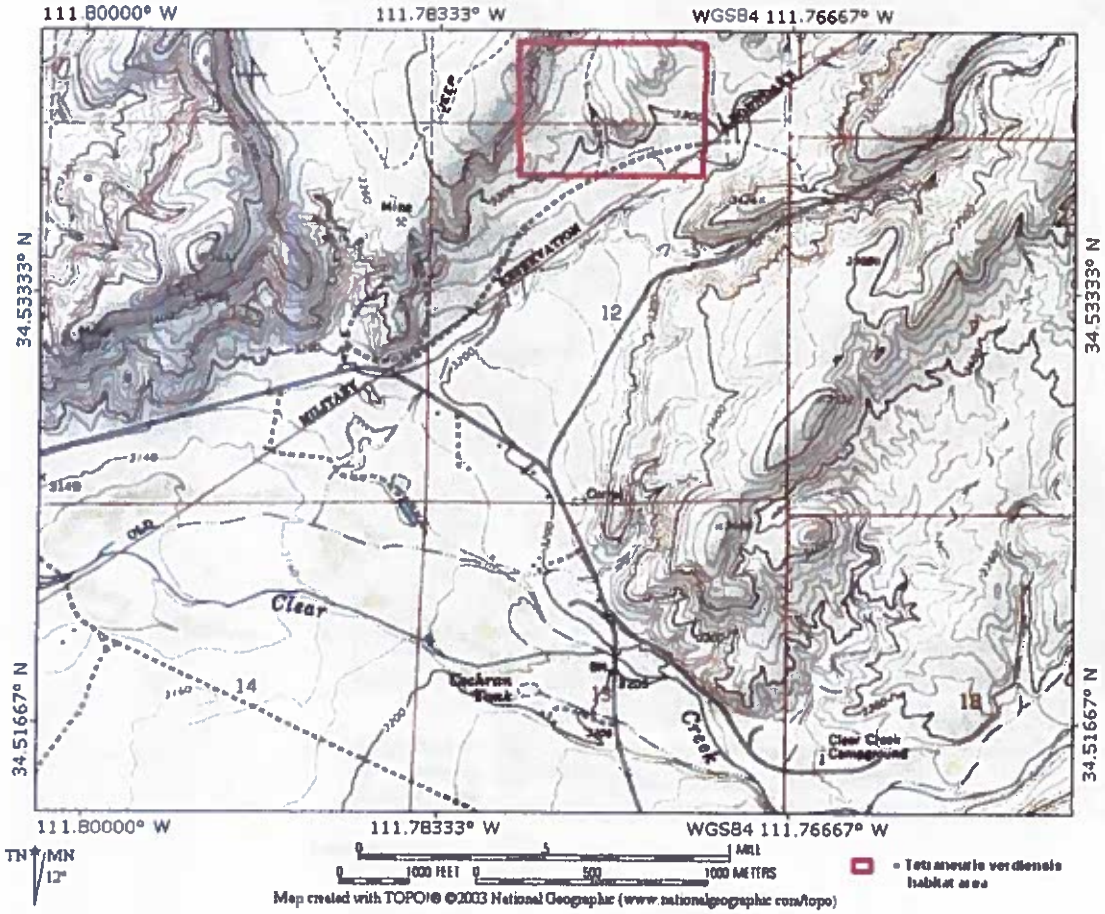
Our surveys in April-May of 2007-2008 found similar results. We surveyed the type location, and a three mile radius around it, documenting occurrences of *T. verdiensis* with a GPS unit (see attached map). We did not find any *T. verdiensis* outside of the previously documented areas. We did not observe any *Tetraneuris* on Middle Verde Road (where *T. acaulis* var. *arizonica* has been documented) to make any comparisons.

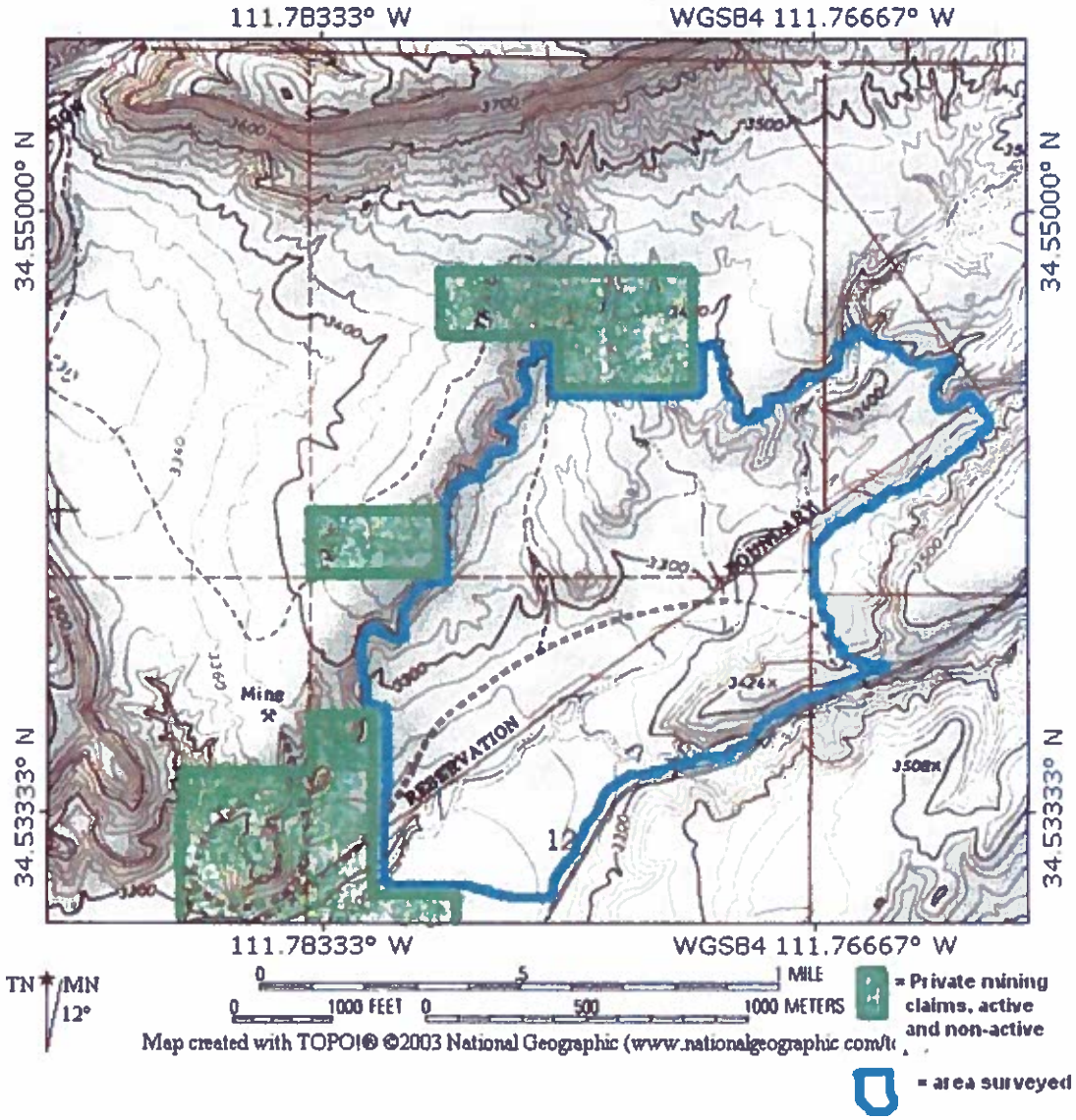
We visited potential *Tetraneuris* habitats near the type specimen. Potential habitat was identified as bright white limestone soil outcrops. Many of the sites had similar associated species, including three Forest Service Sensitive species (*Eriogonum ericifolium var. ericifolium, Salvia dorrii,* and *Polygala rusbyi*), but did not have any *Tetraneuris.*

On April 8, 2008 I visited The Arboretum's *Purshia subintegra* transplant experiment site in limestone soil near Cottonwood (UTM 12S 409883E 3844744N). This area is approximately 17 miles from the *Tetraneuris* site, and has similar, white Verde Formation soils. While checking on the transplant experiment, I came across some *Tetraneuris*. I only located three individuals, all of which were in flower. Two of the three flowers had ray flowers and disc flowers, and one had only disc flowers. All three individuals had dwarf habit, relatively short broad leaves, and a long-pilose vestiture. I did not collect any plant material, as the population was extremely small. (photos are attached). These individuals seemed like *T. verdiensis* to me, except that not all of them had entirely discoid heads. They could be a type of hybrid.

We visited the type specimen population area five times in late March through mid May 2007. Previous literature suggested that peak flowering time for this species occurred in May. However, our earliest visit on

3/27/07 found some individuals flowering. Peak flowering time occurred through the month of April. Approximately 50% of the plants were in flower. No seeds were observed. Our visits in March-May 2008 found similar flowering times. The first signs of fruit set were observed in late May, and seeds were found in June. Seeds were at prime dispersal, where if we showed up a day later, they might have all been swept away with the wind. Our observations on seed timing show that this species, as with many of the Asteraceae, need constant vigilance to catch the seeds at the appropriate time.




111.78333° W
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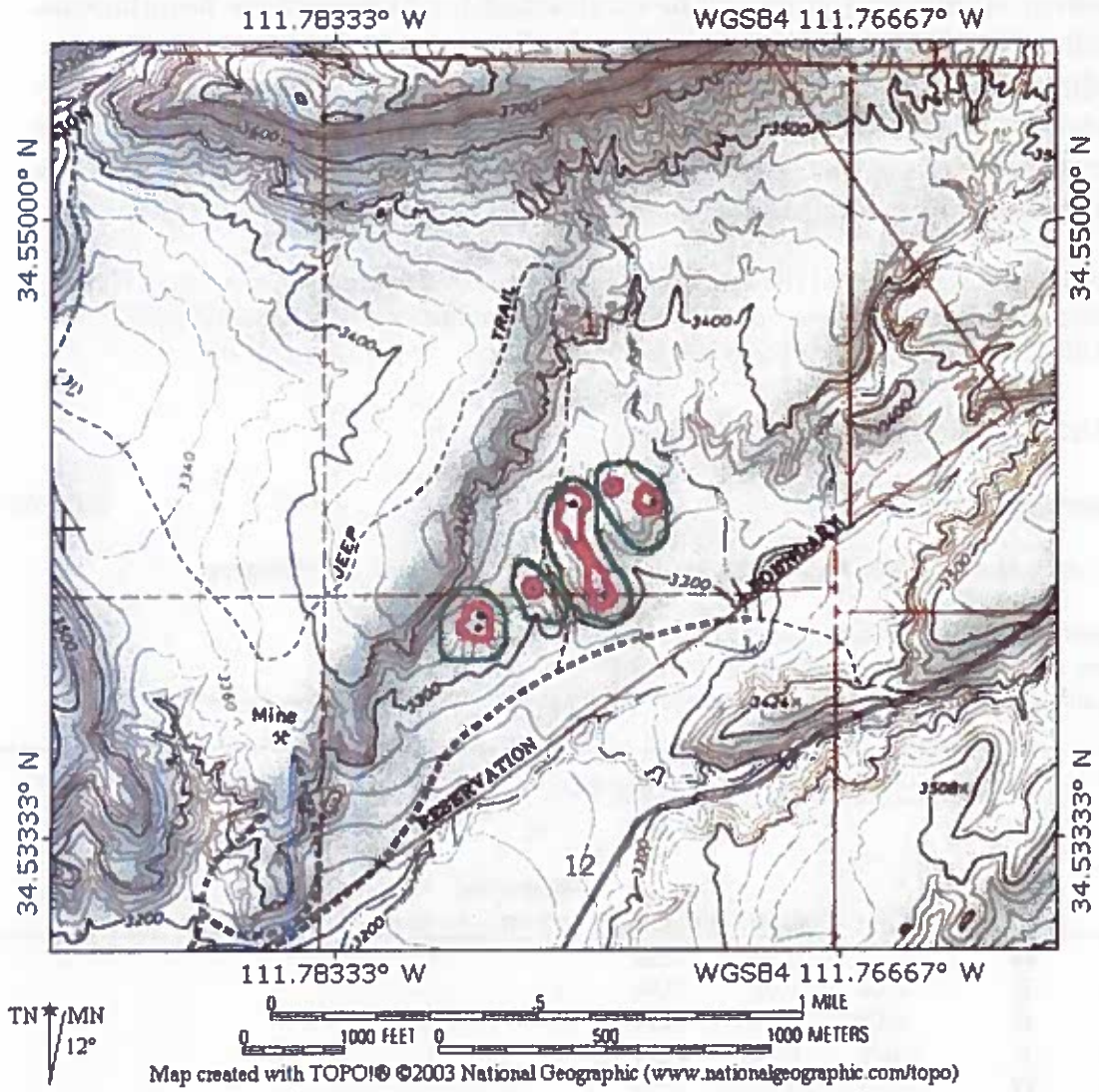
= Private mining claims, active and non-active
= area surveyed
Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/t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0 1000 FEET 0 500 1000 METERS
Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)
• = population center
= population boundary
= "four low hills"

Objective 3: Permanent monitoring plots will be established for at least three populations. Individual plants will be tagged/marked and measured using several measures of performance, including plant size and volume, flowering and fruiting, and seed set. Observations on potential pollinators will be made, and insects seen visiting flowers will be collected to look for transfer of pollen. Statistical power analysis will be used to determine whether the population-level data sample size is adequate to follow trends over time.

A Forest Service Research Permit was acquired (Forest Service Special Use Authorization Amendment Number 57) to install three permanent monitoring plots on June 21, 2007. Plot locations are: #1= 12S 0429322E 3847424N, #2= 12S 0428913E 3822335N, #3= 12S 0428996E 3822364N.

Demography Data:

***Tetraneuris verdiensis* demography** **5/14/2007**

Plots set up and read by: Sheila Murray, Kristin Haskins, Donna Chapman, Justine Kusner, Joe Policastro

three transects were established, two on type specimen hill and one on the hill to the north
We surveyed 0.5 m to either side of the transect to create a 20m² plot
QUAD = 0.5 m x 0.5 m quadrat, counted # of individuals, average stem height and width, noted flowering stems

Plot 1 GPS 0 point: 12S 0429322E 3847424N RUNS SOUTH TO NORTH

Position 1	Position 2	Aspect	height	width	phenology	flowering stems	flowering in quad	veg ind. in quad	notes
8.8	0.2	W	0.04	0.04	VEG				
12.38	0.13	E	0.06	0.03	FLW	1			
12.03	0.04	E	0.08	0.03	FLW	1			
12.03	0.08	E	0.075	0.02	FLW	1			
14.04	0.07	W	0.01	0.012	VEG				
14.04	0.1	W	0.011	0.02	VEG				
14.04	0.16	W	0.02	0.03	VEG				
12.55	0.1	E	0.065	0.04	VEG				
12.65	0.03	E	0.02	0.02	VEG				
12.68	0.05	E	0.02	0.035	VEG				
13.26	0.24	E	0.025	0.025	VEG				
19.01	0.125	W	0.08	0.03	FLW	1			
14.46	0.33	E	0.01	0.02	VEG				
14.52	0.32	E	0.01	0.025	VEG				
14.53	0.37	E	0.01	0.02	VEG				
14.73	0.31	E	0.01	0.02	VEG				
14.73	0.33	E	0.01	0.01	VEG				
14.91	0.19	E	0.01	0.01	VEG				
15.53	0.19	E	0.01	0.02	VEG				

Plot 2		GPS 0 point: 12S 0428913E 3822335N				RUNS SOUTH TO NORTH			
Position 1	Position 2	Aspect	height	width	phenology	flowering stems	flowering in quad	veg ind. in quad	notes
9.74	0.41	W	0.02	0.01	VEG				
12.02-12.52	QUAD	E	.05-.20	.01-.05				28	
9.92	0.15	W	0.02	0.02	VEG				
9.92	0.2	W	0.09	0.04	FLW	1			flower browsed
9.95-10.45	QUAD	W	.015-.025	.01-.03				10	
12.56-13.06	QUAD	E	.01-.03	.01-.03				8	
10.49	0.32	W	0.06	0.04	FLW	1			
10.57-11.07	QUAD	W	.01-.05	.01-.03		1,1	2	6	flower dead
11.12	0.27	W	0.01	0.03	VEG				
11.34-11.84	QUAD	W	.06-.18	.01-.03		1	1	4	one plant adjct to Hymenoxyss p,
12.48-12.98	QUAD	W	.01-.02	.005-.17				7	
18.5	0.46	E	0.02	0.03	VEG				
18.63	0.32	E	0.02	0.04	VEG				
18.76	0.49	E	0.01	0.01	VEG				
18.83	0.46	E	0.03	0.04	VEG				
19.45	0.5	E	0.01	0.01	VEG				
19.53	0.5	E	0.02	0.04	VEG				
19.57	0.49	E	0.02	0.02	VEG				
19.6	0.49	E	0.02	0.02	VEG				
19.63	0.48	E	0.015	0.03	VEG				
19.69	0.47	E	0.02	0.06	VEG				large plant, 5 rosettes connected
14.25	0.46	W	0.06	0.03	FLW	2			
14.23	0.48	W	0.01	0.01	VEG				
13.7-14.2	QUAD	W	.005-.07	.005-.06		1,1	2	12	

Plot 3		GPS 0 point: 12S 0428996E 3822364N				RUNS NORTH TO SOUTH			
Position 1	Position 2	Aspect	height	width	phenology	flowering stems	flowering in quad	veg ind. in quad	notes
1.1	0.5	W	0.05	0.04	VEG				
1.12	0.37	W	0.03	0.03	VEG				

1.12	0.49	W	0.03	0.15	VEG				
1.23	0.47	W	0.04	0.03	VEG				
1.61	0.47	W	0.02	0.02	VEG				
1.72	0.27	W	0.02	0.08	VEG				
1.95	0.07	W	0.08	0.15	VEG				
4.25-4.75	QUAD	W	.02-.07	.01-.03		1	1	8	
5.38	0.4	W	0.03	0.04	VEG				
5.42	0.36	W	0.15	0.15	VEG				
5.65	0.37	W	0.06	0.02	VEG				
6.81	0.01	W	0.15	0.07	FLW	4			
7.27-7.77	QUAD	W	.01-.11	.01-.09		1	1	7	in assoc.with Hymenoxys sp.
4.3	0.08	E	0.04	0.01	VEG				
4.43	0.2	E	0.03	0.08	VEG				
6.56	0.28	E	0.09	0.02	FLW	1			
6.57	0.29	E	0.05	0.05	VEG				
7.46-7.96	QUAD	E	.01-.1	.005-.04		1,1,2	3	4	
14.73-15.23	QUAD	E	.005-.02	.005-.05				6	
15.38	0.4	E	0.03	0.04	VEG				
15.38	0.348	E	0.02	0.03	VEG				
15.97	0.48	E	0.02	0.04	VEG				
16.08	0.46	E	0.03	0.03	VEG				
16.08	0.49	E	0.03	0.03	VEG				
16.1	0.22	E	0.02	0.03	VEG				
18.16	0.19	E	0.01	0.02	VEG				
18.24	0.24	E	0.02	0.01	VEG				
19.44	0.01	E	0.07	0.02	FLW	1			
19.14-19.64	QUAD	W	.01-.09	.01-.05		1	1	8	
18.8	0.49	W	0.02	0.06	VEG				
16.45	0.4	W	0.02	0.04	VEG				
16.42	0.4	W	0.02	0.05	VEG				
14.84	0.14	W	0.02	0.02	VEG				
14.45	0.16	W	0.07	0.06	FLW	1			

General Notes:

All plants (with the exception of two) seemed to be out in the open, no shade or nurse plants. Also, contrary to previous literature, some plants growing on slopes of mesa, and in small washes on mesa, but reaffirming previous literature, not found on steep edges of mesas or in bottomlands with similar soil. Much OHV use in the area, will be interesting to see if the plants are still in the tracks of the OHV later on.
(in Plot 1, OHV track occurs from 10.00-13.00 meters)

All plants seemed to be in full flower, no flower buds were observed in the area at this time. In late April, many plants had flowered, and many more were still budding. We will go back and check for seed timing later this month.

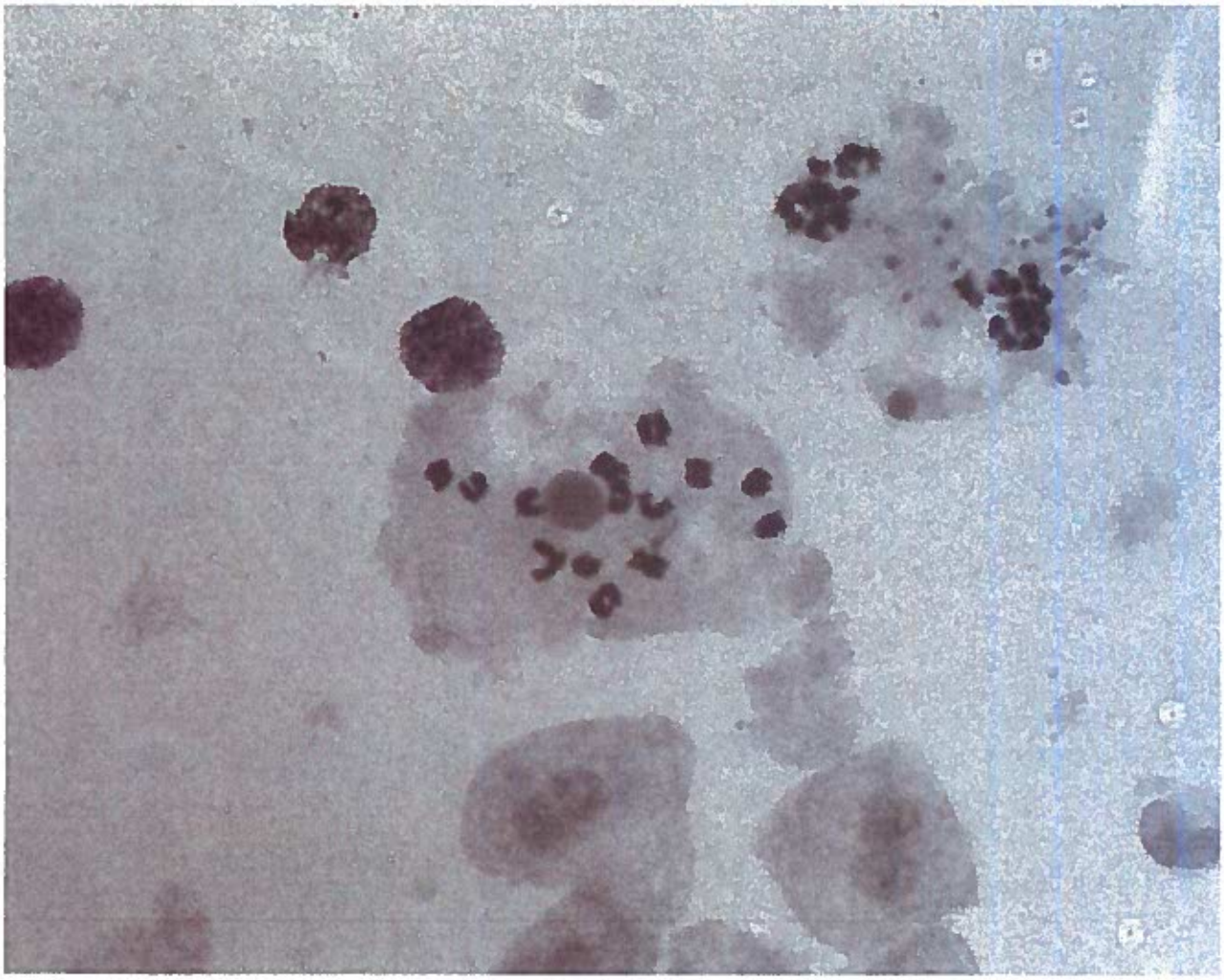
Browsing observed, many scat in area, from rabbit, mule deer, javelina.

No pollinators observed on *Tetraneuris*. Bees and flies in area, plus a few blue butterflies.
Need to go back in early morning or late evening. Was hot today, 95 degrees predicted.

A summary of chromosome counts for *Tetraneuris* was prepared in Bierner and Turner (2003). The only species missing a count was *T. verdiensis*. Michael Windham has provided most of the recent chromosome analysis. Following a protocol provided by him, we collected *T. verdiensis* flower buds from the type location in June of 2007. The results are as follows (Unpublished data, Michael Windham, 2008):

"I did get good chromosome preparations from the buds you sent. The population of *Tetraneuris verdiensis* you sampled is diploid, with 14 pairs of chromosomes in the first division of meiosis (see attached photo). This base number agrees with all recent reports for the genus (there are old, unconfirmed reports of n = 15). Let me know if you need any other information. All the best....Michael"

Figure 1. *Tetraneuris verdiensis* chromosome counts. Photo by M. Windham.



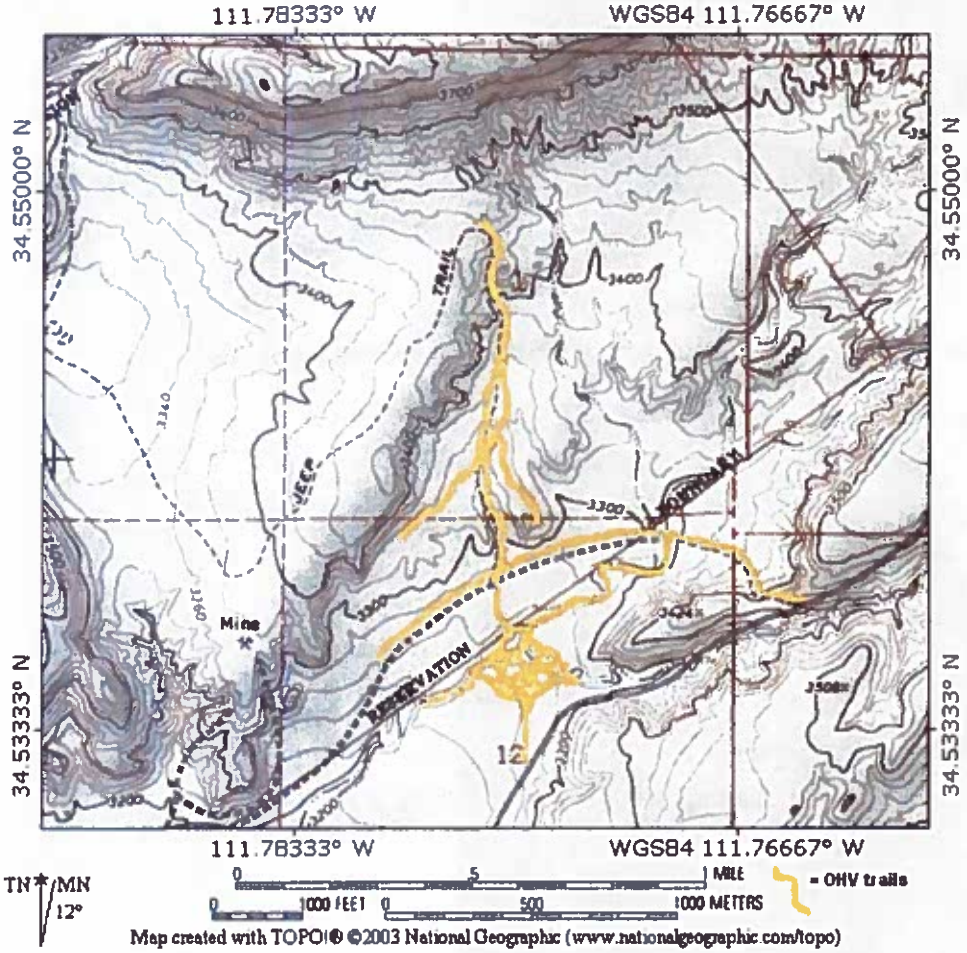
Objective 4: Seed will be collected following the Revised Genetic Sampling Guidelines for Conservation Collections of Rare and Endangered Plants of the Center for Plant Conservation (Guerrant et al. 2004). The Arboretum is a charter member of the CPC. Seed will be placed in long-term storage at the National Seed Storage Laboratory. Germination trials will be conducted to produce plants for genetic and breeding system research, for horticultural potential, and for *ex situ* maintenance at The Arboretum.

The type specimen site was visited periodically in March, April and May to assess timing for seed set. Seeds were then collected June 3, 2008. Approximately 2500 seeds were collected. A portion of the seeds (app. 2000) were sent to the Seed Bank at Bend, Oregon for final storage. The remaining 500 seed will remain at The Arboretum for germination trials in 2009.

Objective 5: Demographic and population data will be analyzed, and final reports prepared on the species' status and recommended conservation management actions.

Our surveys have concluded that populations of *Tetraneuris verdiensis* are limited to the four low hills previously documented by Godec (2000). The populations occur on U.S. Forest Service Lands. However, the gypsum mine located adjacent to the population could have additional potential habitat, or populations. We were unable to get permission to survey on the mining lands, but a visual assessment led us to believe that it is highly probable that *T. verdiensis* is there. Future work should include these private mining claims as areas of consideration.

Heavy off-highway vehicle use was observed in and around the populations. This type of recreation is very popular in this area.



The environmental damage caused by the OHVs is severe and includes, soil erosion, uprooting of individuals, and compaction of the soils. We would recommend to the Forest Service to prevent OHV's from accessing the tops of the gypsum hills where *T. verdiensis* occurs. We observed a small, two-strand barbed wire fence that seemed to be for this purpose on the type specimen hill. However, the fence is in severe disrepair, and many places have been smashed down with boulders to allow OHVs to drive over. This fence could be repaired and strengthened.

Photos: (Sheila Murray, The Arboretum at Flagstaff)

May 14, 2007: Sheila Murray and volunteer Joe Policastro monitoring the demography plot

April 17, 2007: A small individual of *Tetraneuris verdiensis* beginning to flower

April 17, 2007: A small individual of Tetraneuris verdiensis in flower

April 17, 2007: A typical individual of *Tetraneuris verdiensis* in flower

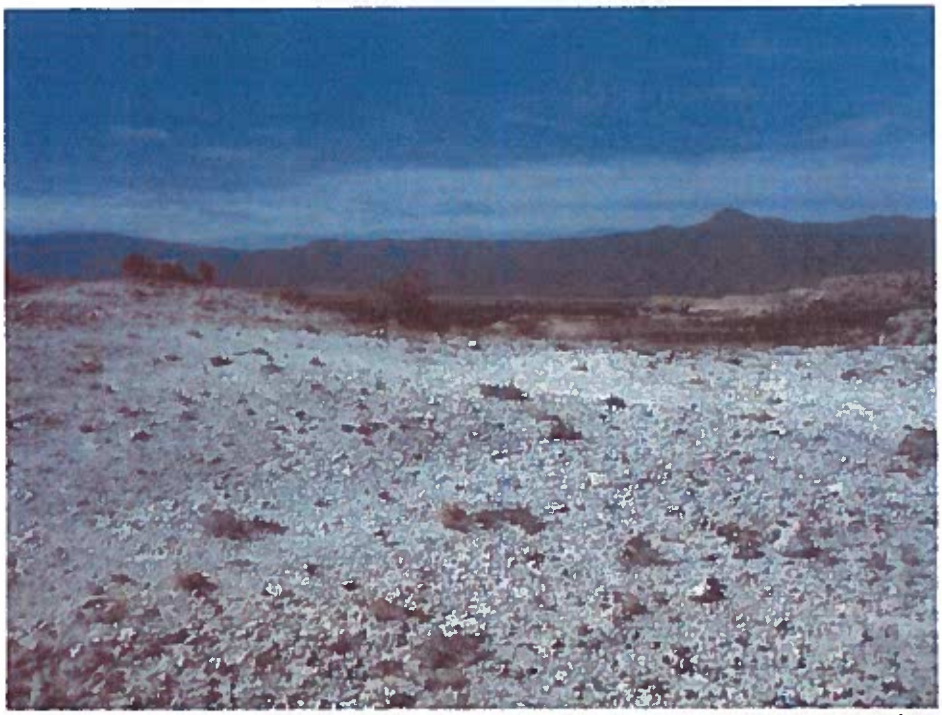
April 17, 2007: An individual *Tetraneuris verdiensis* in flower, with *Eriogonum ericifolium* nearby

April 17, 2007: *Tetraneuris verdiensis* habitat

May 14, 2007: *Tetraneuris verdiensis* habitat, with OHV tracks running through the middle

May 14, 2007: OHV tire tracks in Plot 1

May 14, 2007: Near *Tetraneuris verdiensis* habitat, heavy OHV use



May 14, 2007: *Tetraneuris verdiensis* habitat, with private gypsum mine in far background

April 18, 2008: *Purshia subintegra* habitat

April 18, 2008: *Tetraneuris sp.* in *Purshia subintegra* habitat, ray and disc flowers present

April 18, 2008: ***Tetraneuris sp.*** **in** ***Purshia subintegra*** **habitat, ray and disc flowers present**

April 18, 2008: ***Tetraneuris sp.*** **in** ***Purshia subintegra*** **habitat, only disc flowers present**

Field Visit to *Tetraneuris verdiensis* location

Introduction

On April 3, 2015 we made a field visit to re-locate the rare edaphic species *Tetraneuris* verdensis (Verde four nerve daisy). This rare species was first described in 1996 and grows on four low hills in the Verde Formation east of Camp Verde. I was accompanied to the site by Laura Moser.

Tetraneuris verdiensis was first described by Denham and Turner in 1996. They described the habitat as being on "the southeastern-most" end of the Verde formation where the habitat was comprised of a series of low flat-topped hills composed of gypsum with marl. The distribution of it is apparently limited to these four low hills. Godec (xxxx) stated that a total of 18 low hills with similar habitat were searched in the area but only the four known sites contained *Tetraneuris verdiensis*. We obtained location data from a report prepared in 2008 by Sheila Murray from the Arboretum at Flagstaff. She and others established a series of demography plots on the four hills mentioned above.

Results

We used the coordinates for the first plot to begin navigating to the site but soon discovered that one of the UTMs was erroneous. However, the general location of the habitat was readily apparent by the presence of the four low hills and we were able to locate the habitat. The soil of the Verde Formation is generally described as flashy white and these hills were no exception.

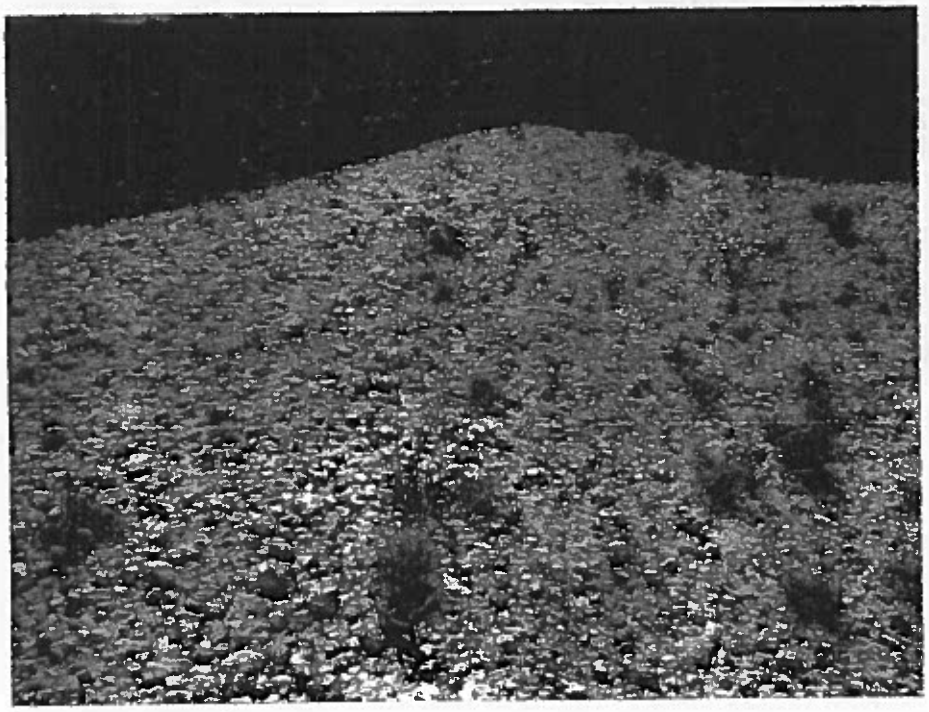


Figure 1. Photo showing general habitat of hill top.

As we arrived at the low hills and climbed to the top of one we almost immediately found *Tetraneuris verdiensis* with each of us locating different small groups almost immediately. The plants on the hill top were as described by others who had visited the area. They were all very small, hairy and lacked ray flowers. We observed some of the plants in bloom but some in vegetative condition. All plants regardless of species were very small as if stunted by the harsh environment. Some of the associated species we observed included three Region 3 sensitive species; Verde Valley sage (*Salvia dorrii* ssp. *mearnsii*) heath-leaf wild buckwheat (*Eriogonum ericifolium* var. *ericifolium*) and Rusby milkwort (*Polygala rusbyi*). We also observed several common species such as crucifixion thorn, creosote bush and globe mallow which were confined to the lower slopes. On the hilltop we observed *Polygala alba*, *P. scopariodes*, small cliffrose plants, a small three-awn grass, little bluestem (*Schizachyrium scoparium*) a small paintbrush with red leaves (*Castilleja applegatei*), and *Cryptantha*. We also observed scattered snakeweed and gray thorn shrubs.

We made no attempt to census the population, nor did we relocate the transects established by Sheila Murray in 2007. We did not search all of the hills, instead focusing on the first we encountered.

Figure 2. Tetraneuris in foreground with short grasses and Eriogonum.

Figure 3. Tetraneuris that has not bloomed yet.

Figure 4. Paintbrush

Figure 5. Crypthantha.

Figure 6. Biotic crust

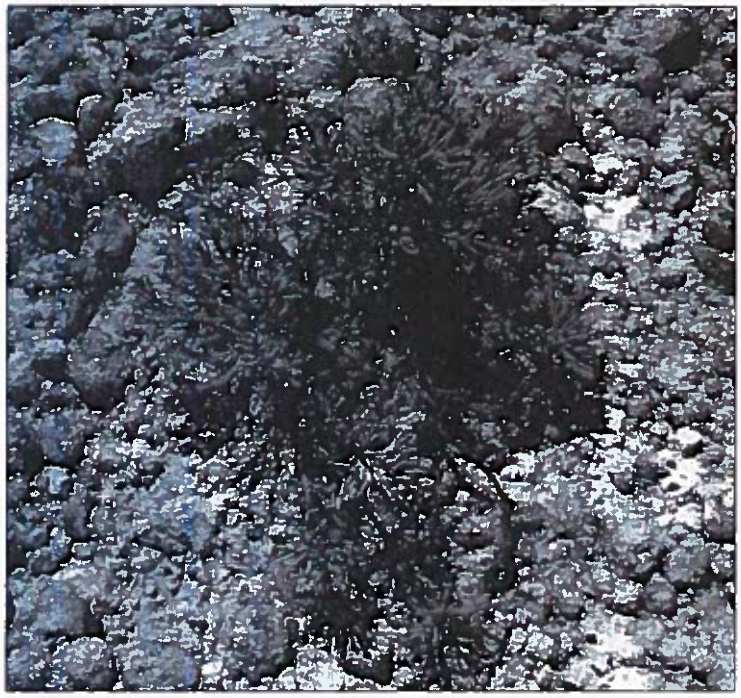


Figure 7. Verde Valley Sage.

Figure 8. Small cliffrose

Several of the roads along Highway 260 that lead into the site have been blocked off. We tried to access the area through the landfill and through the Camp Verde Gypsum Mine. We found the mine road locked and gated with no through access. We finally gained access by taking a side road off Forest Road

for a short distance and then hiking to the site. Once on the site we were very close to the edge of the mine itself and were able to see the material piles.

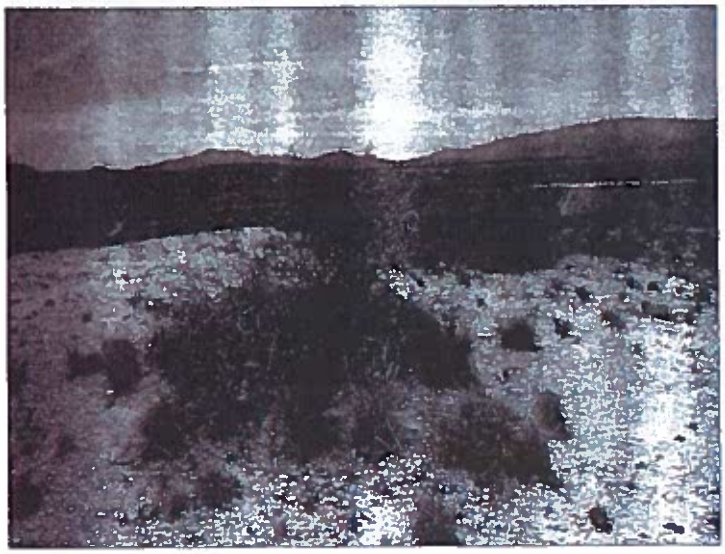


Figure 9. Habitat with mine in background

When we were returning from the site, we observed several plastic pipes that seemed to mark a boundary. The mine could possibly expand in the future into the area of the four low hills. I am currently following up to find out if there are recent and valid mining claims for the area. If the mine expands into the area or another is opened, the operations could remove the material supporting the plants and severely reduce or remove the habitat. Complete removal would likely mean that the species would be extinct as there are no additional records of it elsewhere.

Another threat to the area is off-road vehicle travel. We observed several trails in a major wash in the area but none on the hill we visited. Sheila Murray had documented impacts to the area as well. We did not see the extent of damage she documented in her report but we only surveyed a small portion of the area.

Debra L. Crisp, Forest Botanist, April 22, 2015

References

Denham, R. A., and B. L. Turner. 1996. A new species of Tetraneuris from the Late Tertiary Formation of central Arizona. Phytologia 81(1):5-?
Murray survey report

See Tetraneuris file.

Distribution and Taxonomic Discussion of *Tetraneuris verdiensis*, an Apparently Rare Edaphic Endemic from the Verde Valley of Arizona

DANIEL J. GODEC

SWCA, Inc.

Abstract: *Tetraneuris verdiensis* was first published in 1996. It appears to be closely related to *Tetraneuris acaulis* var. *arizonica*. The closest known location of *T. acaulis* var. *arizonica* is approximately 7 miles northwest of the known *T. verdiensis* locations, which are 5 miles east of Camp Verde. *Tetraneuris verdiensis* is significant in that no other entirely discoid populations, or series of populations, of *Tetraneuris* have been reported. *Tetraneuris verdiensis* populations are consistently discoid, which separates them from *T. acaulis* var. *arizonica*. The type locality is on the top of a low hill of a gypsum stratum of the Late Tertiary Verde Formation. Denham and Turner (1996) stated that additional populations occur on the tops of the adjacent small hills within this stratigraphic unit. Results of a survey of all of the similar gypsum hills and mesas in this area east of Camp Verde are presented, along with population sizes for each gypsum hill where this species occurs. The morphological similarities and differences between *T. verdiensis* and *T. acaulis* var. *arizonica* are discussed, as well as the taxonomic status of *T. verdiensis*.

During recent investigations of rare plant distributions for the Arizona Rare Plant Field Guide (in preparation), a recently named species from the Late Tertiary Verde Formation of central Arizona was first investigated by this author. *Tetraneuris verdiensis* R. A. Denham & B. L. Turner is a dwarf scapose perennial species with densely pilose basal leaves and discoid yellow flower heads (Figure 1). At the time of its discovery in the winter of 1993–1994, this species was known only from the tops of a few small localized gypsum hills within the lacustrine limestone deposits of the Verde Formation. It has been well documented that the lacustrine deposits of the Verde Valley contain several species of endemic, disjunct, and relict plants from different floristic communities (Anderson 1996, Denham and Turner 1996).

To understand the floristics of the Verde Valley's lacustrine deposits, it is important to look at the geologic and climatic history of that region. The Verde Valley is in an area of central Arizona where the northern limits of the Sonoran Desert come into contact with the Transition Zone. The Transition Zone is a relatively narrow geologic province below the Mogollon Escarpment that consists of closely spaced mountain ranges with narrow basins (Anderson 1996, Titley 1984). Approximately 15 million years ago, this geologic province was formed during the mid-Miocene Basin and Range Disturbance, which initially resulted in the formation of a series of sub-Mogollon enclosed basins through tectonic uplifting and subsidence, as well as volcanic activities. During the Late Tertiary period, these enclosed basins subsequently filled with large quantities of water, where lacustrine deposits with interbedded ash flows were laid down into limy tuffs (Anderson 1996, Damon et al. 1984, Denham and Turner 1996). The Late Tertiary Verde Formation was created during this process, as well as several other geologic lacustrine formations in disjunct sub-Mogollon basins (Anderson 1992, 1996). See Figure 2 for a map of the Transition Zone and the formerly enclosed basins, where lacustrine deposits formed during the Late Tertiary Period.

During the Pleistocene glacial periods that occurred approximately 11,000 years ago, as subsidence ceased and precipitation increased, stream throughflow between basins increased and caused erosion to occur. In the Verde Valley area, this erosional activity exposed the undeformed lacustrine deposits of the Late Tertiary Verde Formation, allowing plant species to colonize the area (Anderson 1996, Nations et al. 1982). Floristic communities within these deposits vary drastically with changes in the substrates of this formation. The upper portion of this formation, near Cottonwood, consists of narrow interbedded layers of limestones, mudstones, and marls. The lower end of the formation, from near Camp Verde and extending to the south and east, was formed in the deepest parts of the prehistoric lake. This area consists primarily of larger limestone deposits and evaporites, such as gypsum and deposits of salts (Anderson 1992, Denham and Turner 1996). In this portion of the Verde Valley, numerous narrow bands of peculiar soils running in a northeast-southwest direction are exposed. In this area one

Figure 1. *Tetraneuris verdiensis*.

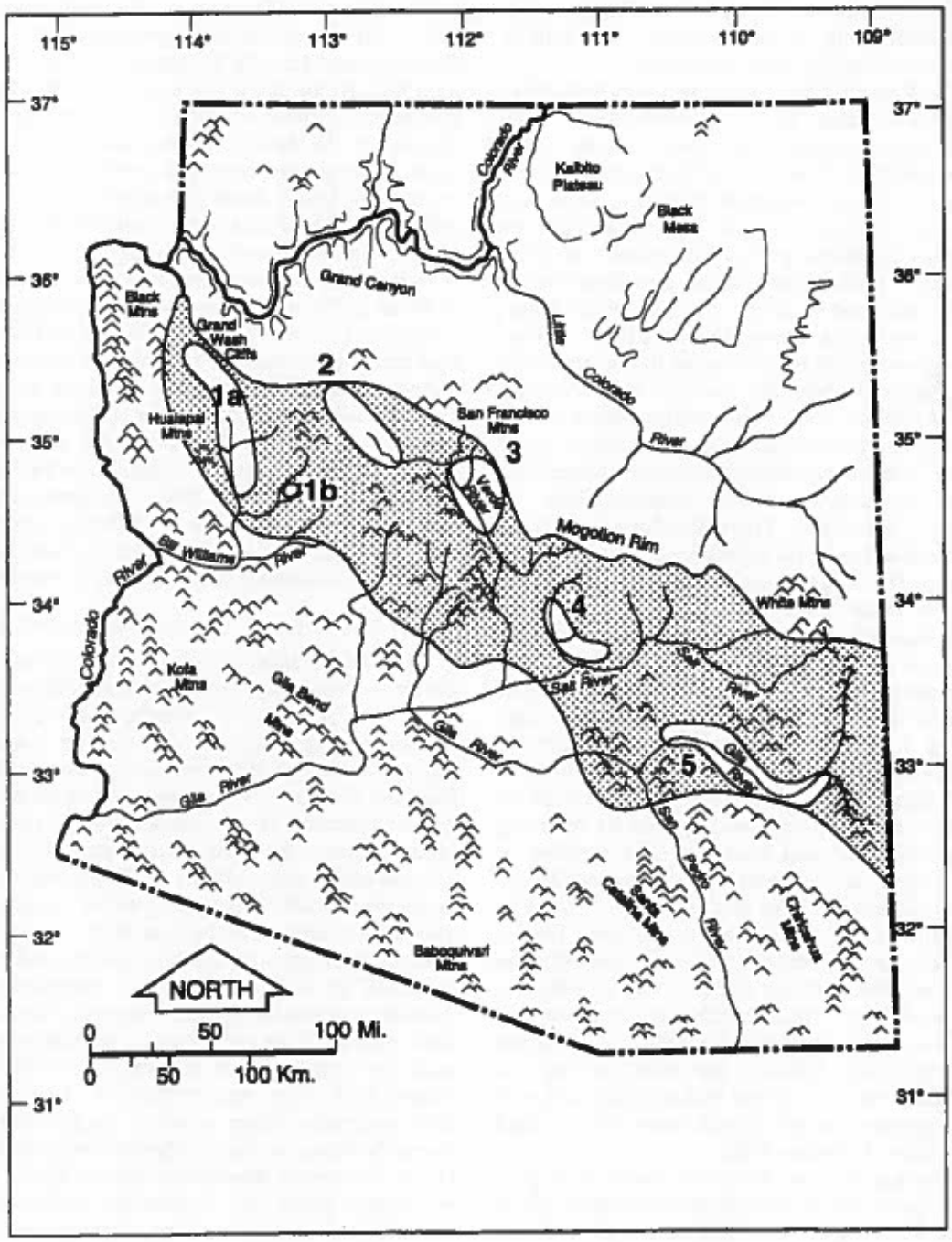


Figure 2. The Transition Zone geologic province of Arizona (shaded area). 1a = Hualapai Valley, 1b = Burro Creek, 2 = Chino Valley, 3 = Verde Valley, 4 = Tonto Valley, 5 = San Carlos Basin.

can go from areas of limestone to areas of gypsum and marl, and eventually to areas of volcanic tuff. Each of these substrates accommodates a unique floristic community. *Tetraneuris verdiensis* apparently occurs only on these gypsum marl soils of the lower end of the Verde Formation.

The Verde Valley is approximately 300–450 m higher in elevation than any of the other Transition Zone basins and is the closest of these basins to the Mogollon Rim. As in all of the other Transition Zone basins, the climate is more equable than the surrounding desert areas. This equable climate exhibits a biseasonal precipitation pattern of 25 cm or more of annual precipitation, a moderate mean annual temperature, and a relatively small difference between the annual high and low temperatures as compared to other areas in the surrounding deserts (Raven and Axelrod 1978, Axelrod 1979, Anderson 1996). The combination of these climatic characteristics causes the climate to be similar to the more mesic climate of the Miocene in the Southwest (Axelrod 1979, Anderson 1996).

The Verde Valley Transition Zone basin is located within the *Larrea tridentata–Canotia holacantha* series of the Arizona Upland Subdivision of the Sonoran Desertscrub biotic community (Brown 1994). However, the relatively infertile soils of the lacustrine deposits within the Verde Valley form a sharp edaphic contrast and generally exclude species that are typically dominant in this biotic community, including *Larrea tridentata* (DC) Coville, *Parkinsonia microphylla* Torr., and *Canotia holacantha* Torr. This opens the way for the occurrence of disjunct, endemic, and relict species by reducing competition for soil moisture. The number of elevationally and geographically disjunct species, as well as endemic and relict species, is higher in the Verde Valley than in any of the other Transition Zone basins (Anderson 1996). Apparently, the sharp edaphic contrast of the lacustrine deposits compared to the typical volcanic and metamorphic soils found in the Sonoran Desert has been the most important factor in the establishment and continued existence of the endemic, disjunct, and relict species that are found there (Gankin and Major 1964, Anderson 1996).

Climatic changes in the Southwest have provided the sources of these floristic curiosities in the Verde Valley area. Through studies of pack rat middens, it has become clear that the Verde Valley contained pine-oak-juniper woodland with chaparral as recently as the Late Tertiary period. This vegetation arrived in that area as a result of Pleistocene glacial cycles, which caused pinyon-juniper woodlands to extend southward into the lower elevation deserts of the Southwest, including areas that today contain the modern Sonoran and Chihuahuan Deserts (Betancourt 1986, Van Devender 1977, Van Devender and Spaulding 1979, Van Devender and King 1971, Lanner and Van Devender 1981). At the end of the most recent Wisconsin glaciation, approximately 11,000 years ago, the climate of the Southwest became warmer and drier, causing pinyon-juniper woodland to retreat from these lower deserts (Anderson 1992). The relatively infertile soils of the Verde Valley's lacustrine limestone deposits have apparently offered refugia for many genera that historically occurred in the area. Because of the biseasonal precipitation pattern and relatively equable climate, and the fact that many of the species dominant in the modern Sonoran Desert do not grow on these infertile soils, the lack of competition for soil moisture has enabled genera typically associated with pine-pinyon-juniper vegetation to remain in the Verde Valley (Anderson 1992, 1996). The genus *Tetraneuris* is no exception, as it typically occurs at higher elevations in the Great Plains, Great Basin, and Rocky Mountains (Denham and Turner 1996).

Distribution of *Tetraneuris verdiensis*

The distribution of *Tetraneuris verdiensis* and the sizes of each population segment of this apparently rare plant were investigated and documented during this study. This research was conducted in May of 1999 and 2000. Based on Denham and Turner's (1996) description of the habitat and distribution of this species and on personal observations of the habitat of the type location, all suitable and similar habitats within a 3-mile radius of the type locality were surveyed for this species. This habitat consists of the tops of low chalky hills composed of gypsum crystals, gravel, and marl, occupied by a dwarf sub-shrub community of numerous perennial species (Figure 3). The dominant species of the type location include edaphic endemic species, such as *Eriogonum ericifolium* Torrey & A. Gray var. *ericifolium*, *Salvia dorrii* (Kell.) Abrams subsp. *mearnsii*, and *Lesquerella cinerea* S. Wats., as well as *Hymenopappus filifolius* Hook., *Penstemon thompsoniae* (Gray) Rydb., *Krameria erecta* Willd. ex J. A. Schultes, *Melampodium leucanthum* Torr. & A. Gray, *Townsendia incana* Nutt., *Thymophylla acerosa* (DC) Strother, *Frasera albomarginata* S. Wats., *Houstonia rubra* Cav., and *Castilleja chromosa* A. Nels. Other less dominant species present at the type location include Arenaria eastwoodiae Rydb. var. adenophora Kearney

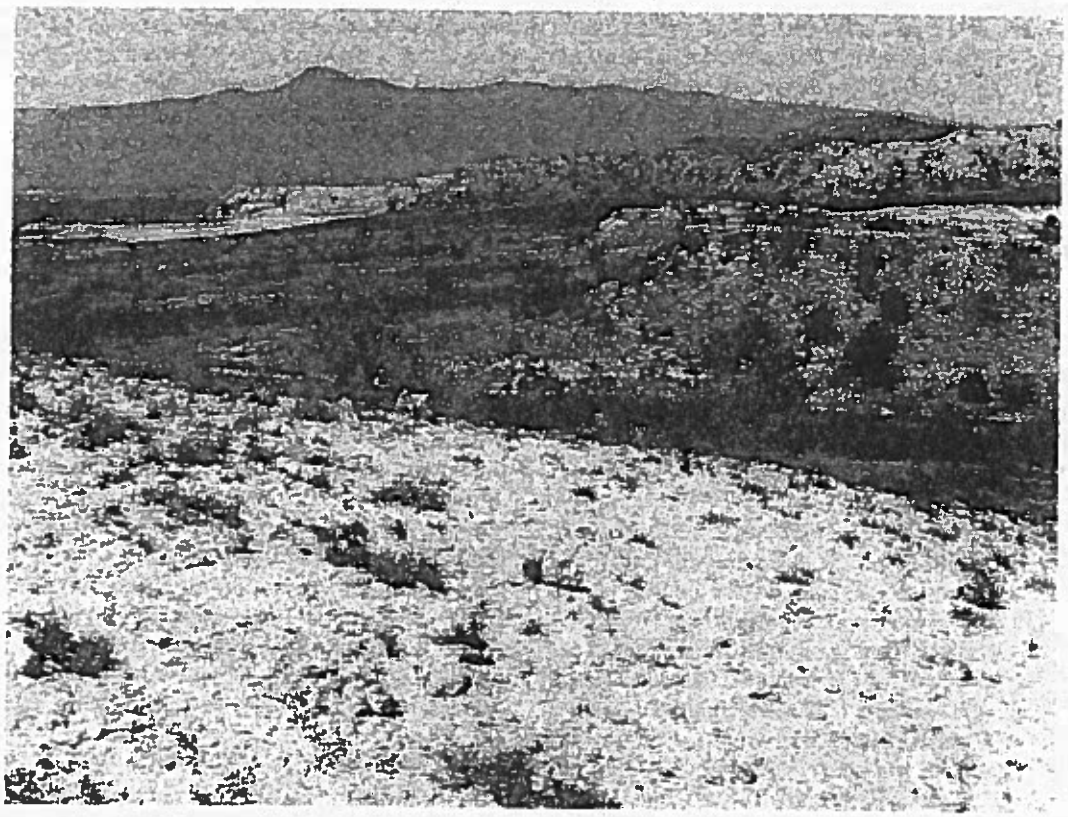


Figure 3. *Tetraneuris verdiensis* habitat.

& Peebles *Polygala alba* Nutt., *Ceanothus greggii* Gray, *Echinocereus engelmannii* (Parry ex Engelm.) Lem., *Ephedra torreyana* S. Wats., *Lepidium* sp., *Purshia stansburyana* (Torr.) Henrickson, *Rhus trilobata* Nutt., and *Juniperus coahuilensis* (Martinez) Gaussen ex R. P. Adams.

In total, 18 low hills and mesas in the nearby area were searched for the presence of this species, based on soil characteristics and the presence of similar vegetation. Each of these areas contained sub-shrub communities with many of the same species found at the type location. Of the 18 study areas, only 10 appeared to contain the same mix of gypsum, marl, and gravel substrates as the type location. These unique gypsiferous soils of the type location are limited to the southeastern portion of the Verde Valley, where the deepest portions of the ancient lake were located.

Tetraneuris verdiensis was found only on the tops of four low hills: the type location and three low hills adjacent to it. The distribution of this species was patchy, and primarily limited to the tops of the hills or on gently sloping areas at the edges of the tops. Steeper sides of these hills, and areas at the base of these hills with very similar soils and sub-shrub communities, were conspicuously lacking this species. In addition, this species was not found in areas on the same hilltops where thicker shrub communities and more gravelly or cobbly soils were present.

This taxon occurred in seven distinct population segments on these four low hills. The number of plants present in each of these population segments was estimated (Table 1), and each population segment was sampled with 5 m wide transects of variable length. Five transects were sampled in each of the smaller population segments, which covered nearly the entire distribution of the segments and the very specific habitat each occurred in. In the two largest population segments, where

Table 1. Population estimates for each population segment of *Tetraneuris verdiensis*.

Population segment no.	No. transects sampled	No. plants per sq m	Size of area sampled in sq m	Estimated no. plants
1	8	0.39	4,621	1,808
2	5	0.08	532	43
3	5	0.11	550	62
4	8	0.28	2,148	602
5	5	0.36	926	341
6	5	0.07	789	58
7	5	0.31	1,224	384
Totals			10,790	3,298

the amount of suitable habitat was more abundant, eight transects were surveyed for this species and approximately half of the area in those population segments was sampled. The average number of plants per square meter was determined for these transects, and a population estimate was made based on the total area covered by the population segment and the total number of plants per square meter in the sampled transects.

The total number of plants is approximately 3,298. It should be noted that the exact number of plants is difficult to determine with this species, as multiple underground stems are commonly associated with one plant. The estimated total area of suitable habitat occupied by this species was 10,790 sq m (1.08 hectares). Based on the transects sampled for this study, the overall average of plants per square meter is estimated to be 0.23. By far, the largest population segment can be found at the type location, where approximately 1,808 plants occur. Several of the population segments occurred on small patches of suitable habitat, which supported less than 100 plants. Only in the largest population segment was the phenology of this species examined. An estimated 51% of plants within that population segment were blooming. The only insect pollinator observed was a bee fly (Family Bombyllidae).

Taxonomic Discussion of *Tetraneuris verdiensis*

The genus *Tetraneuris* was first described in 1898 by E. L. Greene and is part of the *Hymenoxys* complex (Asteraceae: Helenieae). In the past century, various botanists have encountered difficulties when attempting to understand generic delimitation within the *Hymenoxys* complex. In light of these challenges, several different treatments of this group have been published. This complex includes taxa referable to *Dugaldia* Cass., *Hymenoxys* Cass., *Macdougalia* A. Heller, *Phileozera* Buckley, *Picradenia* Hook., *Plummera* A. Gray, *Rydbergia* Greene, and *Tetraneuris* Greene. Various taxonomic treatments have recoginized *Tetraneuris* at the generic level, including Rydberg (1914), Robinson (1981), Bierner (1994), and Bierner and Jansen (1998). Others have submerged the genus *Tetraneuris* into *Hymenoxys* (Turner and Powell 1977, Kearney and Peebles 1960, Lehr 1978).

After analysis of the chromosome numbers, chemical characters, and morphological characters of taxa within the *Hymenoxys* complex, Bierner (1994) determined that a reasonable case could be made for either submerging all of the genera in this complex into *Hymenoxys* or for splitting them into the eight genera mentioned above. More recent studies of DNA restriction site variation in *Hymenoxys* and *Tetraneuris* taxa have clearly separated the taxa referable to *Tetraneuris* into a separate branch of the DNA phylogenetic tree from all of the other taxa that were evaluated within the *Hymenoxys* group. These findings were consistent within the taxa studied, with the exception of *Hymenoxys texana*, which produced a phenogram that placed it with *Tetraneuris* (Bierner and Jansen 1998, Spring et al. 1994). Although *Tetraneuris* is a genus closely related to *Hymenoxys*, Bierner and Jansen (1998) discovered that the taxa referable to *Tetraneuris* that they studied formed a monophyletic clade supported by the presence of 40 shared characters and a boot strap value of 100%. This research appears to merit recognition of *Tetraneuris* at the generic level.

The apparently closely related taxon, *Tetraneuris acaulis* (Pursh) Greene var. *arizonica* (Greene) K. L. Parker also occurs in the Verde Valley, where it can be found on the lacustrine limestone deposits and adjacent Mesozoic sandstones. This taxon, common in northern Arizona and southern Utah, reaches the southernmost extent of its range in the Verde Valley, where it has been documented by Denham and Turner (1996) near the town of

Cottonwood and in the Middle Verde Road area by Anderson (1996). The Middle Verde Road population is approximately 7 miles from the known locations of *Tetraneuris verdiensis* but the two have not been documented as occurring together, possibly because of the lack of suitable habitat between them. The most important characteristic distinguishing these two species is the consistently discoid flower heads of *Tetraneuris verdiensis*. Denham and Turner (1996) also stated that *T. verdiensis* differs from *T. acaulis* var. *arizonica* in its dwarf habit, long pilose vestiture, and relatively short broad leaves. However, observations of the latter species in the Middle Verde Road area reveal a population of *T. acaulis* var. *arizonica* that does exhibit a dwarf habit, long pilose vestiture, and relatively short broad leaves (Figure 4). Although the degree of hairiness in this population of *T. acaulis* var. *arizonica* is not as severe as it is in *T. verdiensis*, the characters that these plants exhibit appear to provide evidence of intergradation and intermediate forms between the two taxa.

Discoid individuals have been documented elsewhere in taxa referable to *Tetraneuris*, such as in the case of populations of *Tetraneuris acaulis* Greene var. *acaulis* in Wyoming. There, discoid individuals have been documented within the population as isolated individuals that only differed from the typical form of this species in their rayless condition. Those plants were the basis of *T. eradiata* A. Nelson, but are currently considered to be deviant forms of *T. acaulis* var. *acaulis* (Denham and Turner 1996). Other than *T. verdiensis*, no completely discoid populations or series of populations have been documented within this genus.

Discussion

The results of this research indicate that *Tetraneuris verdiensis* has a severely limited range and very specific habitat requirements. Of 18 hills searched, this species was documented only on the tops of four adjacent hills in the Verde Valley, occurring in seven distinct subpopulations. A total population estimate of 3,298 plants, covering approximately 10,790 sq m (1.08 hectares), was revealed during this study. This taxon is apparently very sensitive to slight changes in soil characteristics, degree of slope, and competition from other plants. Even on the same hills as known populations, this species was not found in areas of more dense shrub cover or in more gravelly-cobbly situations. On the steeper slopes of the sides of these hills, where soils and sub-shrub communities appeared to be very similar, this species could also not be found. Some very small patches of seemingly similar habitat on nearby hills were not occupied by this species at the time of this study, and appear to be available for colonization by this species in the future.

Taxonomically, this species appears to be very closely related to *Tetraneuris acaulis* var. *arizonica*. The two taxa both occur in the Verde Valley, but known locations of these two taxa are separated by a distance of 7 miles and occur in different habitats. The nearest location of *T. acaulis* var. *arizonica* occurred on gently sloping areas in the bottom of the valley, where somewhat more dense shrub communities with less gypsiferous soils were present. Meanwhile, *T. verdiensis* occurred only on the tops of low hills. The entirely discoid flower heads of *T. verdiensis* were consistently observed in all plants and all sub-populations, and not as isolated individuals. In addition, all plants observed in the nearest *T. acaulis* var. *arizonica* population contained ray flowers. However, the long pilose vestiture and dwarf habit of plants within the nearest location of *T. acaulis* var. *arizonica* appeared to be intermediate between the degree of those characters found in *T. verdiensis* and the typical more northern form of this taxon.

Recent genetic studies of the genus *Tetraneuris* by Bierner (1994) and Bierner and Jansen (1998) did not include *T. verdiensis*. To further understand the taxonomy of the species, genetic studies appear to be necessary. It appears possible that *T. verdiensis* would be best treated as a discoid variety of *T. acaulis*. However, without genetic analysis of this taxon, that recognition cannot be made at this time.

Currently, all known occurrences of this species are located on lands owned by the Coconino National Forest. However, privately owned land can be found directly south of the hills occupied by *T. verdiensis*, and some of the hills on that land are currently being mined for gypsum. Although at least one of the hills containing this species is accessible to all-terrain vehicles, the degree of disturbance within the occupied habitat is currently minimal. Protection of these hills would not only benefit *T. verdiensis*, but would also benefit other edaphic endemic species (*Eriogonum ericifolium* var. *ericifolium*, *Salvia dorrii* subsp. *mearnsii*, and *Lesquerella cinerea*) as well as populations of several disjunct species. Simply by retaining these lands under the current Coconino National Forest ownership and management regime, this unique taxon and the rare combination of substrates and

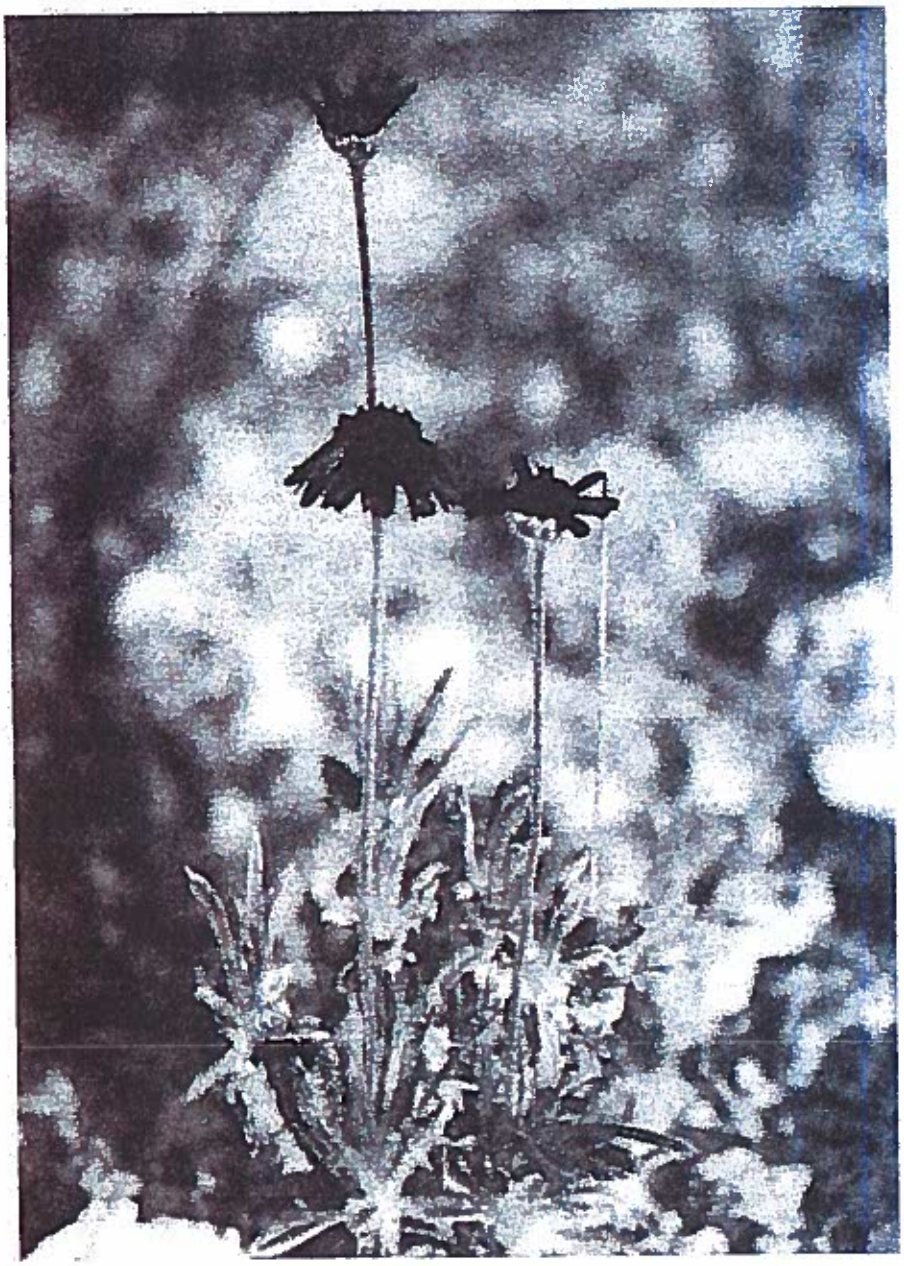


Figure 4. *Tetraneuris acaulis* var. *arizonica*.

vegetation that makes up its specific habitat will be protected. It is possible that more populations are present that were not detected during this survey. Further investigations into the distribution of this plant within the Verde Valley may uncover new populations in the future.

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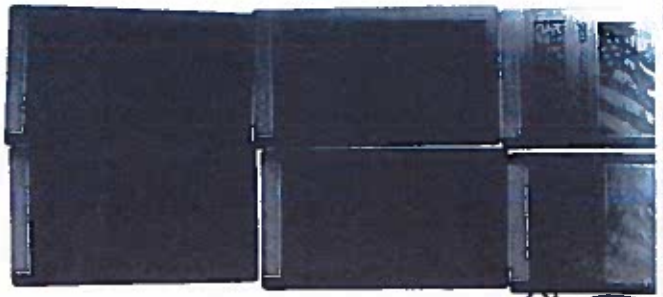

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