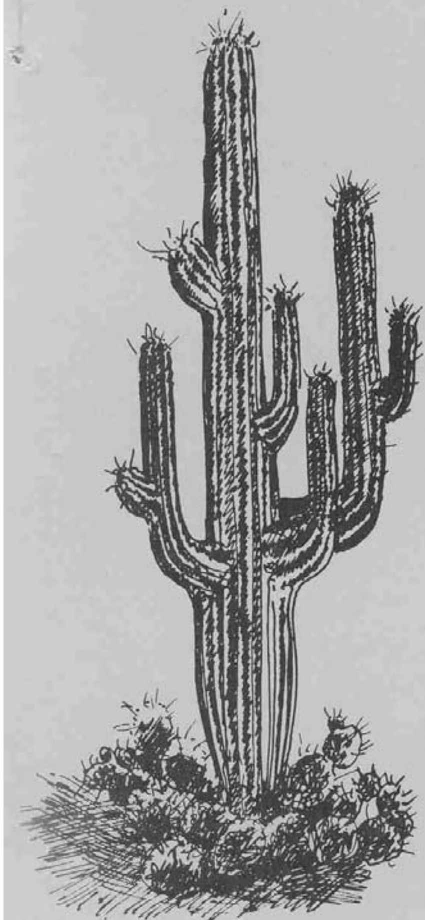

Cooperative National Park Resources Studies Unit

ARIZONA

TECHNICAL REPORT NO. 20

VEGETATION RECOVERY FOLLOWING LIVESTOCK REMOVAL NEAR QUITOBAQUITO SPRING ORGAN PIPE CACTUS NATIONAL MONUMENT

Peter L. Warren and L. Susan Anderson

University of Arizona
Tucson, Arizona 85721

Western Region
National Park Service
Department of the Interior
San Francisco, Ca. 94102

COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
University of Arizona/Tucson - National Park Service

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COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
UNIVERSITY OF ARIZONA
125 Biological Sciences (East) Bldg. 43
Tucson, Arizona 85721

R. Roy Johnson, Unit Leader
National Park Senior Research Scientist

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Peter L. Warren and L. Susan Anderson

The Arizona Nature Conservancy
30 N. Tucson Blvd.
Tucson, Arizona

and

Arizona Remote Sensing Center
Office of Arid Lands Studies
University of Arizona
Tucson, Arizona

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Peter L. Warren and L. Susan Anderson

The Arizona Nature Conservancy
300 E. University Blvd., Suite 230
Tucson, Arizona 85705

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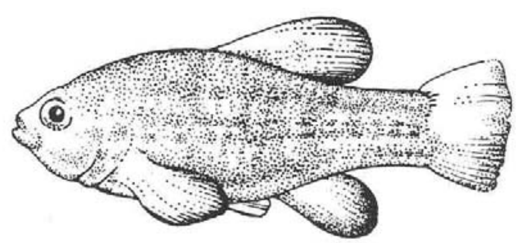


Quitobaquito Science Series, No. 3 -- January 1987
Technical Editors: Peter S. Bennett, Research Scientist
and
R. Roy Johnson, Sr. Research Scientist

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Quitobaquito Spring, and the series of seeps and springs associated with it, have been a focus of human activity for thousands of years. It is one of the few spring-fed sources of fresh water in hundreds of square miles of the most arid part of North America. Until the last family moved away in the 1950's, it had been occupied for generations by Papago Indians and their close relatives the Sand Papagos (Bell et al. 1980; Hayden 1967). Before the Papagos, people of the Amargosa culture had moved into the area from the northwest, perhaps as early as 5,000 years ago (Ezell 1954). The first Europeans are thought to have visited in 1540, and by 1698 Father Kino described "good pastures ... with their irrigation ditches" along the Rio Sonoyta and at Quitobaquito (Hoy 1969, 1970). For over 250 years--until the Park Service bought the rights to Quitobaquito from Jim Orosco, the last Papago resident -- the spring was used to irrigate fields, just south of what is now the pond, and to water livestock.

Although Quitobaquito is the best known of the springs in Organ Pipe Cactus National Monument, the five or six other springs associated with it are perhaps equally important biologically. This series of springs is arranged along a southeast-northwest trending fault on the south side of the Quitobaquito Hills. The major springs in the system are, from the southeast, Aguajita, Quitobaquito, Muddy, Burro, and Williams. Smaller unnamed seeps also lie between Quitobaquito and Burro, and to the northwest of Williams Spring. Quitobaquito has the greatest flow of the springs in the complex and probably has received the greatest man-caused disturbance to its natural condition. Its source has been excavated, irrigation ditches have been dug, a dam has been constructed to capture the resulting increased flow, and fields plowed and cultivated in the flats below the dam. Williams has also been developed to a small degree; a cement trough was installed to capture spring flow, although the area apparently has not suffered agricultural disturbance. The other springs also have been heavily disturbed by man's activities, but to a large extent these disturbances have been restricted to the grazing of domestic livestork.

Springs such as those at Quitobaquito are unusual in the Sonoran Desert, and provide a dramatic contrast to the sparse arid scrub of the surrounding desert. The springs support a diversity of plants and animals that are found nowhere else within many miles (Anderson et al. in prep.; Bowers 1979; Huey 1942). The marsh and surrounding mesquite woodland support a population of breeding bird species such as Yellow-breasted Chat, Hooded Oriole, vermilion Flycatcher, and Western Kingbird, as well as many migrants, that are rare or absent in the surrounding desertscrub (Johnson et al. 1983). The pond itself is occupied by Desert Pupfish and Sonoran mudturtles, all of which have restricted distributions in the area.

This paper documents some of the changes that have occurred in natural vegetation in the Quitobaquito area following removal of domestic livestock from the monument in 1978-79. Our discussion focuses on Williams, Burro and Aguajita springs, but not on Quitobaquito itself, for several reasons. Quitobaquito has been relatively intensively studied for several years while the other springs have, to a large degree, been ignored. Also, Quitobaquito and its counterpart in Sonora, Quitovac, are both maintained in an artificial condition: Quitovac due to agricultural development (Nabhan et al. 1982), and Quitobaquito due to management for wildlife and visitor use. The remaining springs, especially Williams and Burro, may tell us more about the natural ecology of isolated desert springs than the pond at Quitobaquito, which has been greatly modified.

Methods

Between December 1974 and April 1976 several permanent vegetation study plots and numerous photo-points were established in the monument to document vegetation condition. In 1984 we selected several of each in the Quitobaquito area for resampling and rephotographing to document changes that had occurred during the 8 to 9 years since the original sampling.

Permanent Study Plots

One-tenth hectare permanent study plots were established in 1975 to provide baseline data for monitoring vegetation change in the monument subsequent to the removal of livestock (Steenbergh and Warren 1977). Perennial vegetation cover was measured by the line intercept method of Canfield (1941; also see Mueller-Dombois and Ellenberg 1974) along 20-m transect lines that were oriented perpendicular to the long axis of the 20-m x 50-m plots at 5-m intervals, providing a total of 11 parallel 20-m transects per plot. The transect lines were also used to subdivide the plots into ten 20-m x 5-m subplots. Within each of these subplots all perennial plants were identified and counted, for data on total density and species presence.

Three plots were resampled in 1984. These are plot 200, 40 m north of Aguajita Spring; plot 2E1, 0.8 km east of Aguajita Spring; and plot 2E2 2.4 km east of Aguajita Spring. These plots were originally established on a livestock-use gradient from the heaviest use near Aguajita Spring to lighter use away from the spring. Soil texture also shows a slight gradient from plot to plot, with the siltiest, most poorly drained soils close to Aguajita Spring and rockier, more well-drained soils away from the spring (Steenbergh and Warren 1977). All plots were located upland desertscrub vegetation. Most of the photo points however, were located near springs in riparian vegetation that had been heavily disturbed.

The Student t-test (Sokal and Rohlf 1969) was used for statistical comparison of plots between years. Individual line-intercept transects were used as samples for calculating mean cover (N - 11), and density subplots were used as samples for calculating mean density (N - 10).

Photo Points

Photographs taken from points established in 1974 and 1976 provide a permanent visual record of the vegetation in those areas of the monument at that time. Selected points around the springs were rephotographed in April, 1984 to document changes in marsh vegetation that was not sampled with quantitative methods. Photos were taken using a 35-mm camera with a 50-mm lens. The photo points that we rephotographed were originally established near springs where livestock use was heaviest, and thus are not representative of the general condition of surrounding desertscrub. All photos were taken by the authors.

Results and Discussion

The patterns of vegetation change observed in the vicinity of Williams, Burro and Aguajita springs are to some extent similar, but each spring has unique physiographic features which have resulted in some observable differences in the patterns of change between springs. The extent and degree of vegetation change depend in part on the size of the springs and on the species composition of the desert vegetation surrounding them.

Williams Spring

Three distinct vegetation and physiographic zones are recognizable at Williams Spring. The first is the spring source itself and the permanently saturated soil immediately surrounding it. The spring source is located on a broad terrace that supports a stand of mesquite (Prosopis) glandulosa) and seepweed (Suaeda torreyana). The terrace appears to have been formed by deposition of siliceous sinter associated with the spring, perhaps as the spring source moved from place to place, over a long period of time. A grassy saline flat lies below the shallow scarp that marks the edge of the terrace. Water is visible seeping to the surface here and there on the flat, but appears not to be permanent at the surface.

The spring source at Williams was heavily disturbed by livestock. Photographs from 1974 and 1976 show that grass and shrubs at the source were severely cropped and that native marsh species were not present. The ground around the spring was trampled and devoid of herbaceous cover except on the wettest patch of ground and under the protection of a few shrubs (Figs. 1-3). Shaded areas under tree canopies were also trampled by livestock seeking shade. The remains of at least three dead cows were at the spring in 1976, attesting to the severity of the 1974-75 drought.

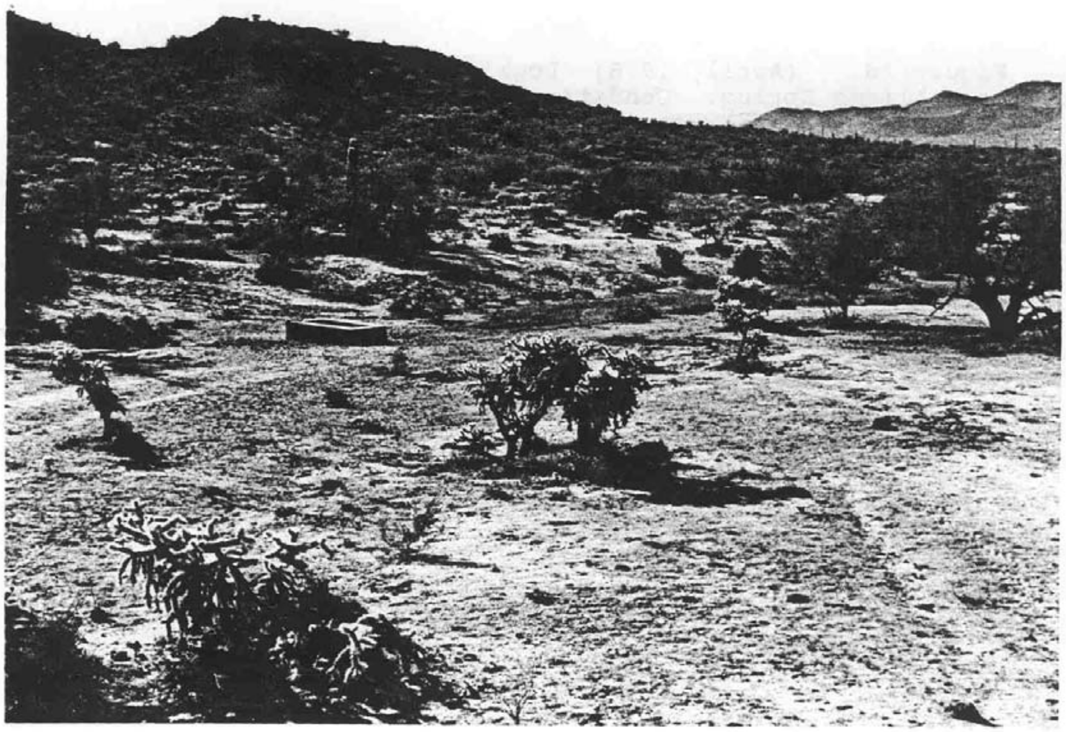
By 1984, only five years after livestock were removed, the spring source had become grown-in with several native marsh species of which bulrush (Scirpus olneyi) and cattail (Typha domingensis) are the most prominent. Around the margin of the saturated marsh area several woody species are increasing including alkali goldenbush (Isocoma acradenia), seepweed, and mesquite. The moist swale below the spring, which had been covered with grazed bermuda grass (Cynodon dactylon), is now dominated by native shrubs.

The major changes observed on the terrace around the spring are an increase in the canopy size of hedged shrubs such as seepweed and an increase in the density of herbaceous annuals (Figs. 4-6 and 1), rather than the addition of perennial species as seen at the spring source. The overall result was a large increase in the vegetation cover on the previously-trampled, silty soil of the terrace.

The saline flat below the terrace (Figs. 7-9) was covered almost exclusively by a sparse stand of saltgrass (Distichlis spicata)in 1976, and, except for the immigration of alkali sacaton (Sporobolus airoides), has not undergone any major change in species composition. The biggest change is an increase in saltgrass cover and its expansion up onto the previously barren scarp of the terrace. The single patch of yerba mansa (Anemopsis californica) on the flat was expanding in 1976, but now appears to be sinking, perhaps as a result of competition with saltgrass.

Figure 1a. (December, 1974) Williams Spring, looking southeast across the cement trough. The ground is heavily trampled and herbaceous ground cover is almost absent in the vicinity of the spring. A swath of closely-cropped bermuda grass extends downstream of the trough on damp soil.

Figure 1b. (April, 1984) The person is standing on the trough (removed in September, 1984) at Williams Spring. A shallow pool (1-1.5 m deep) extends for 3-4 m in diameter around it. Cattail, bulrush and alkali goldenbush have come in on the wet soil and seep weed has recovered on the uplands. Several herbaceous species, especially <u>Macaeranthera arizonica</u>, bush muhly and jackass clover (<u>Wislizenia refracta</u>) have increased in the foreground along with many standing dead annuals.



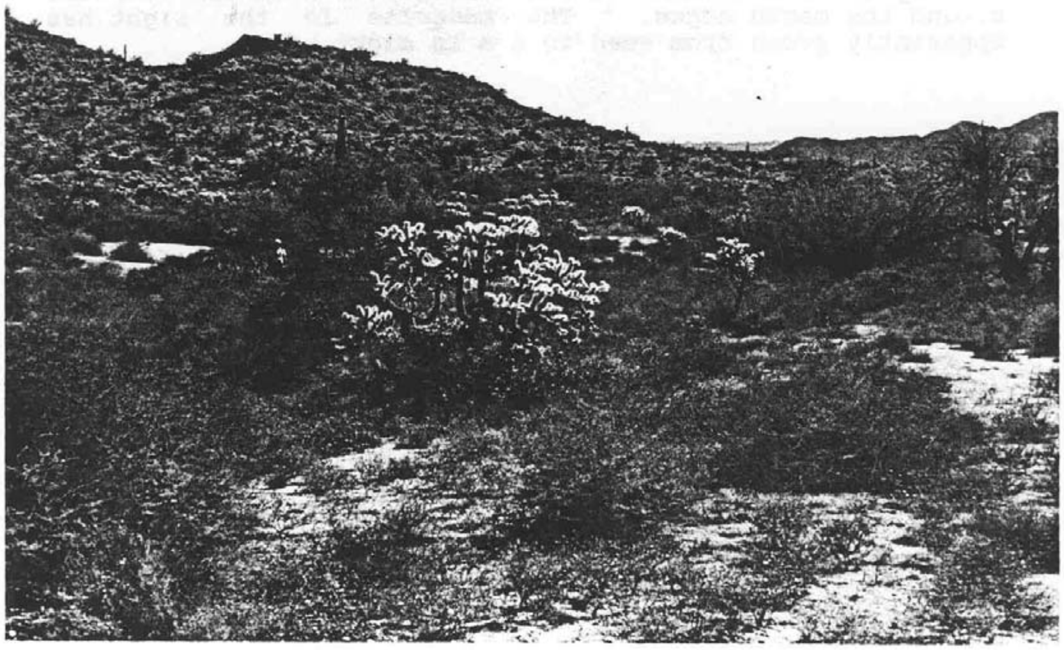


Figure 2a. (April, 1976) Looking north-east at the trough at Williams Spring. Conditions have not changed noticeably since Figure 1a was taken with the exception of the cow skeleton in the foreground -- testimony of the 1974-1975 drought. The moist soil in the center is the only area of herbaceous vegetation on the photo and is dominated by bermuda grass.

Figure 2b. (April, 1984) The person is standing on the Williams Spring trough. Dense bulrush and cattails have come up in the wet soil with alkali golden bush and seepweed around the marsh edges. The mesquite in the right has apparently grown from seed to 4 m in eight years.

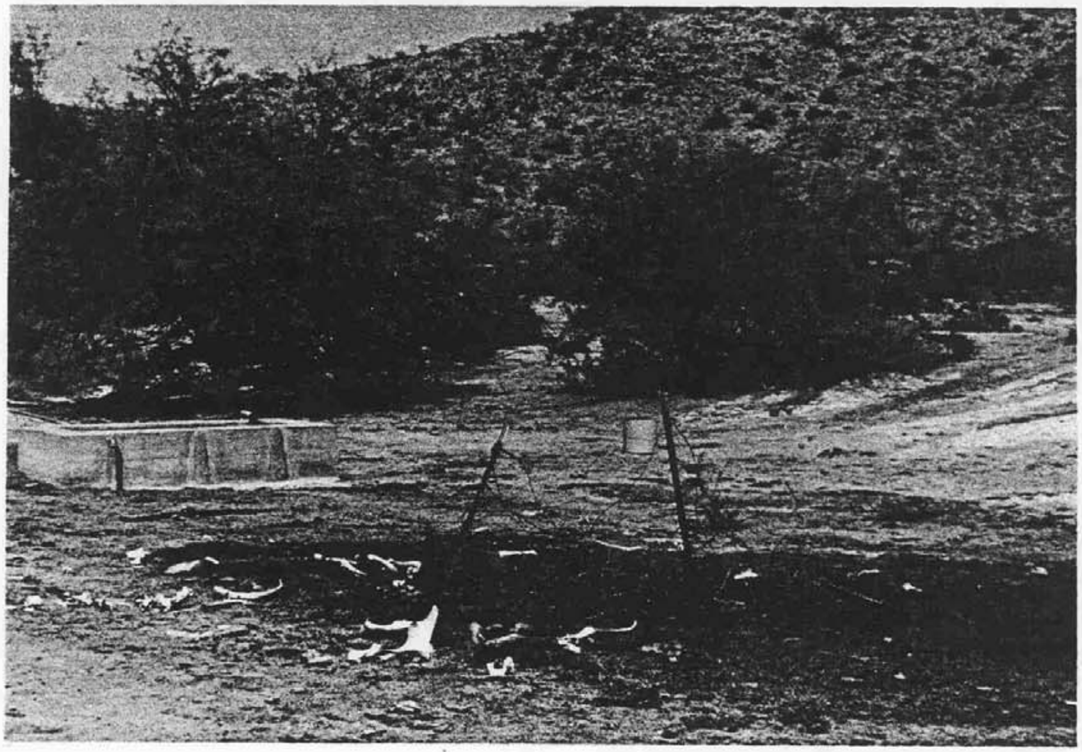


Figure 3a. (April, 1976) The view south from 20 m southwest of the Williams Spring trough. The foreground shows severely browsed seepweed and bermuda grass in the wash bottom.

Figure 3b. (April, 1984) Woody species, especially mesquite, alkali goldenbush and seepweed, have increased markedly. Several mesquite have grown from seed to 4 m in height. Soil in the drainage is muddy with flow from the spring.

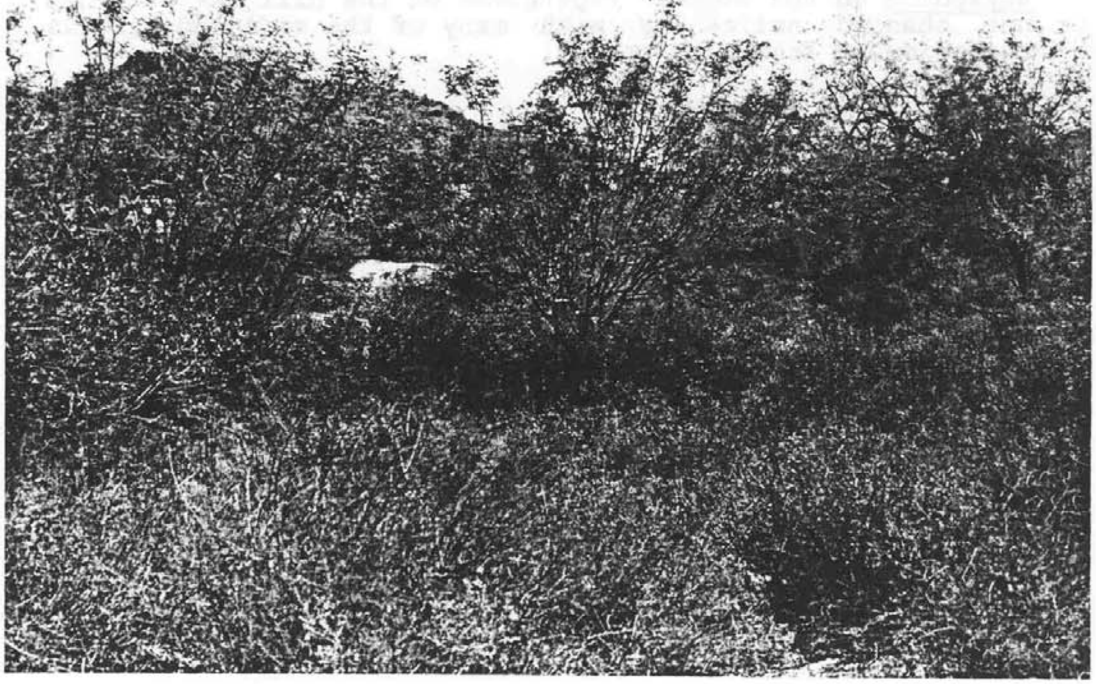
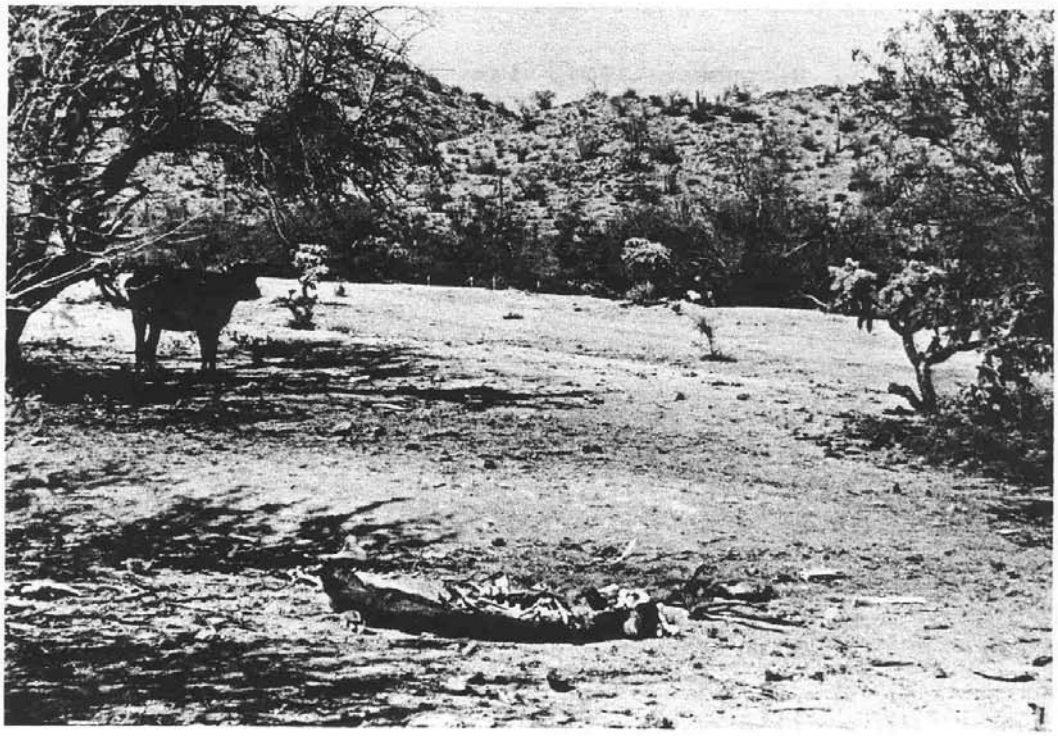


Figure 4a. (April, 1976) View to the north from the same location as Figure 3a at Williams Spring. The fence visible in the background encloses the spring source and excludes livestock from an area of approximately 15 m by 15 m. Water was piped from inside the fence to the trough approximately 20-25 m downstream. The ground is severely trampled, particularly under mesquite trees where livestock seek shade.

Figure 4b. (April, 1984) The luxuriant growth in the foreground is mostly seepweed, with some *Macaeranthera arizonica* on the right. Vegetation on the hill in back has not changed noticeably with many of the same individuals recognizable from both photos.



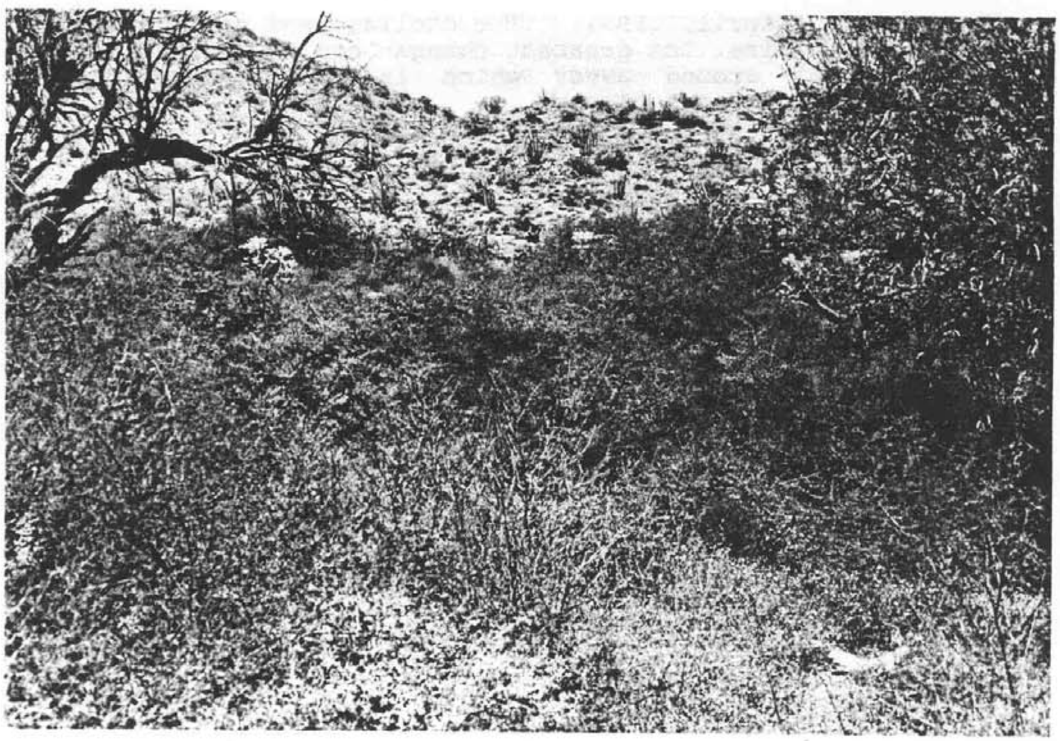
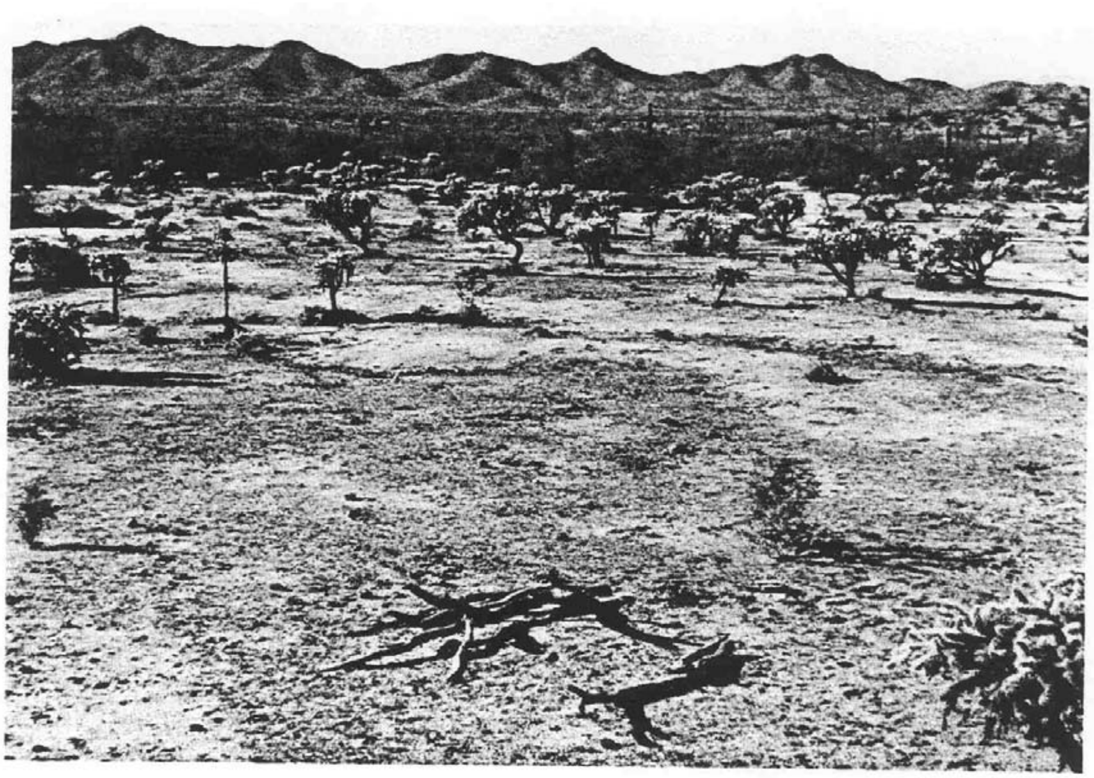


Figure 5a. (December, 1974) View to the southwest from the rise 40 m west of Williams Spring trough. The dominant plants are jumping cholla (Opuntia fulgida) with a few small creosotebush and cropped saltbush. Herbaceous plants are lacking and the ground is heavily trampled.

Figure 5b. (April, 1984) The chollas and saltbush have increased in size. The greatest change can be found in the thick annual ground cover which is mostly Macaeranthera arizonica and jackass clover.



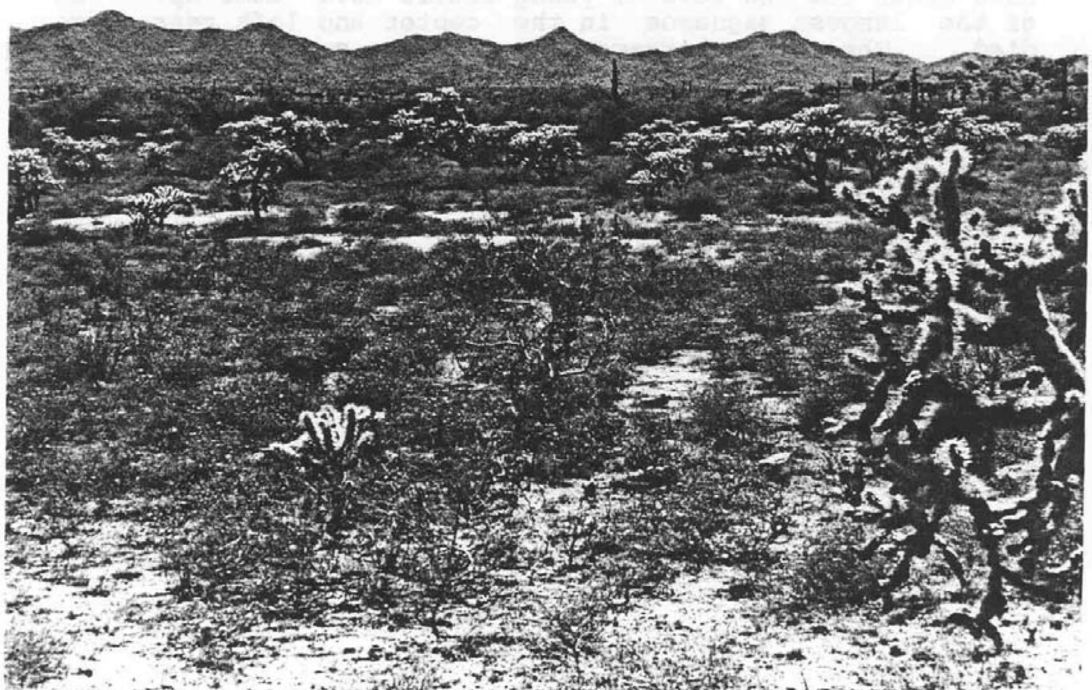
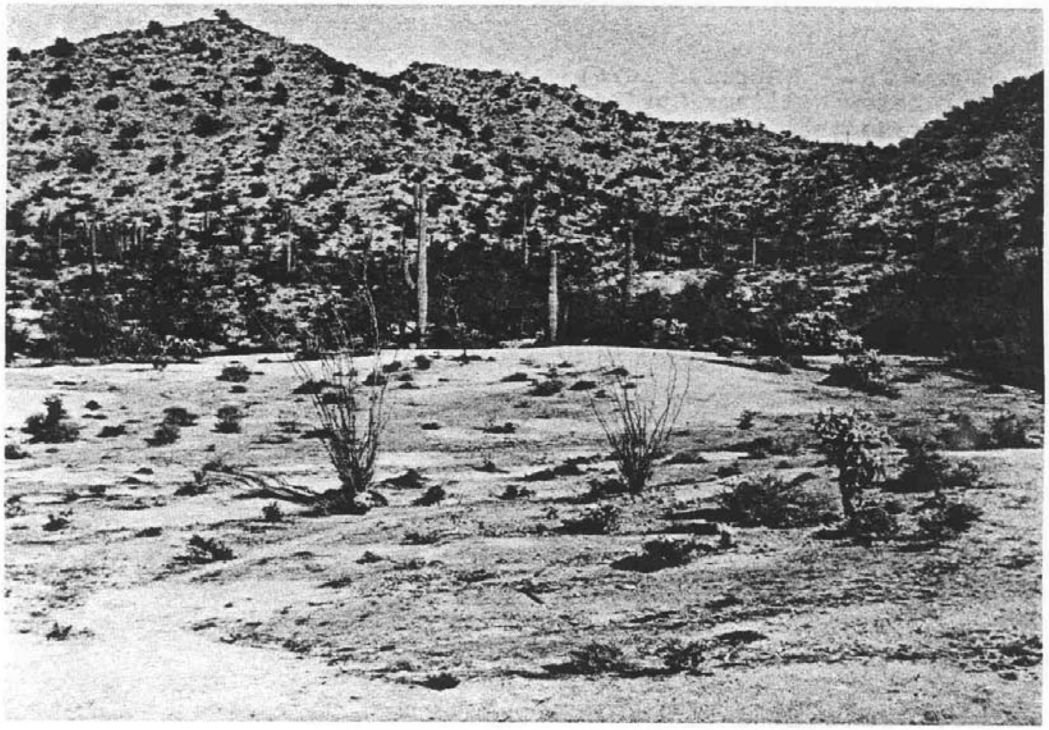


Figure 6a. (December, 1974) Looking northwest from the same location as Figure 5. The plants in the foreground are ocotillo (*Fouquieria splendens*) heavily cropped seepweed and saltbush. The upper spring is just out of the picture in the thicket to the right rear.

Figure 6b. (April, 1984) Seepweed and saltbush canopies have grown out and several young cholla have come up. Two of the largest saguaros in the center and left rear, have died. The new herbaceous ground cover is mostly *Macaeranthera arizonica*, *Euphorbia* sp. and tumbleweed (*Salsola kali*).



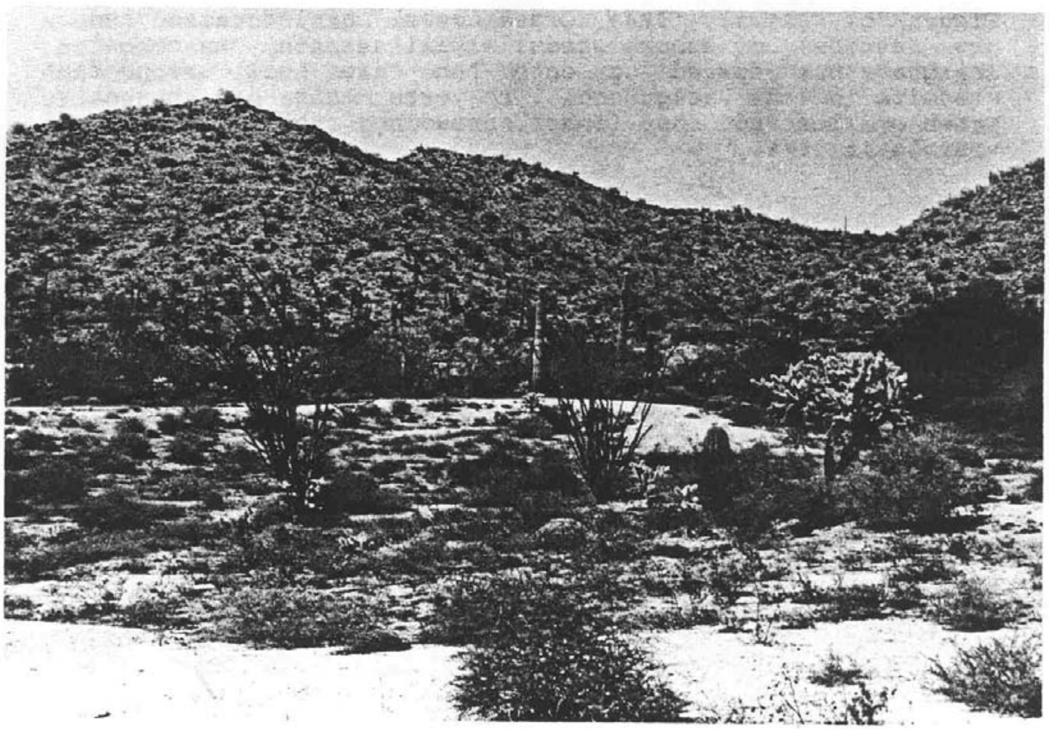
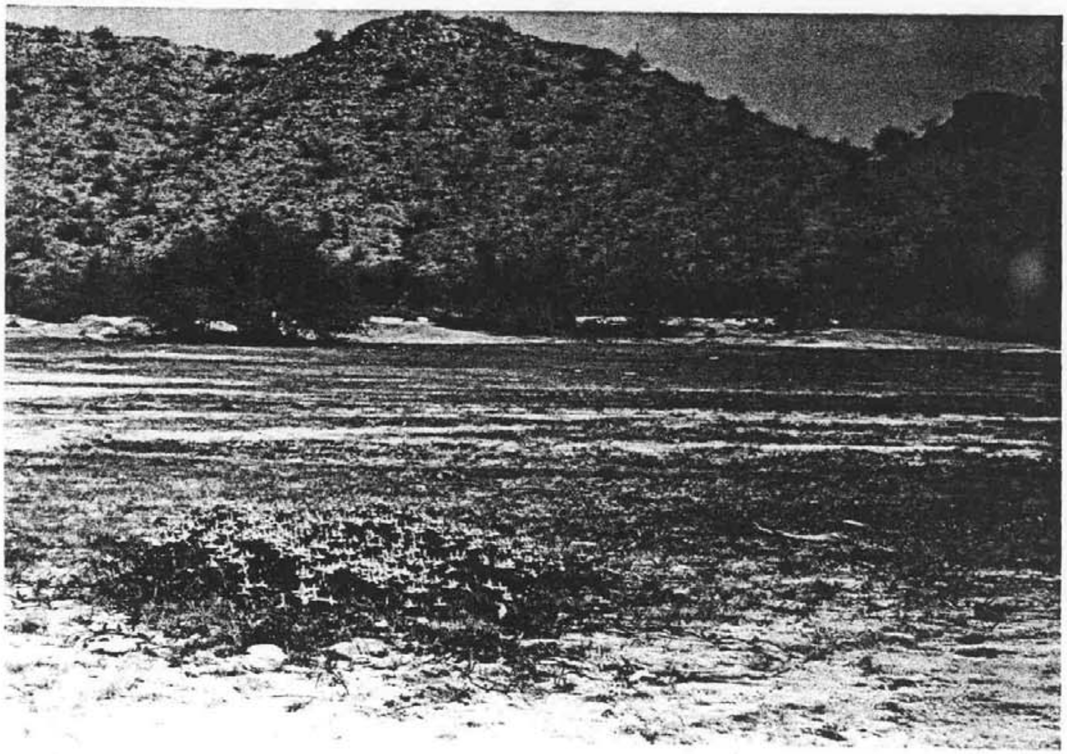


Figure 7a. (April, 1976) Looking east across the saline flat below Williams Spring. The common grass on the flat is saltgrass and the flowering herb in the left front is yerba mansa. The trees in background are mesquite.

Figure 7b. (April, 1984) Grass cover has increased and a new species of bunch grass, alkali sacaton, has come in. Saltgrass has spread up onto the bare soil around the mesquite in the background. The yerba mansa has apparently grown smaller and has fewer spreading stolons than were visible in 1976.



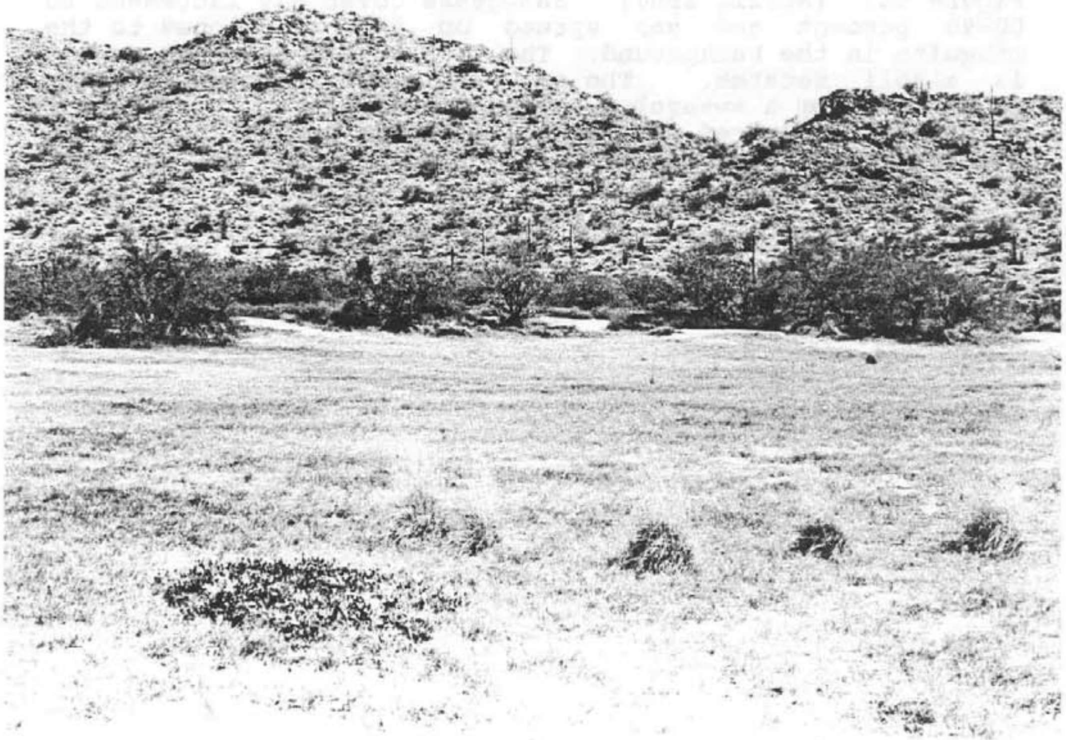
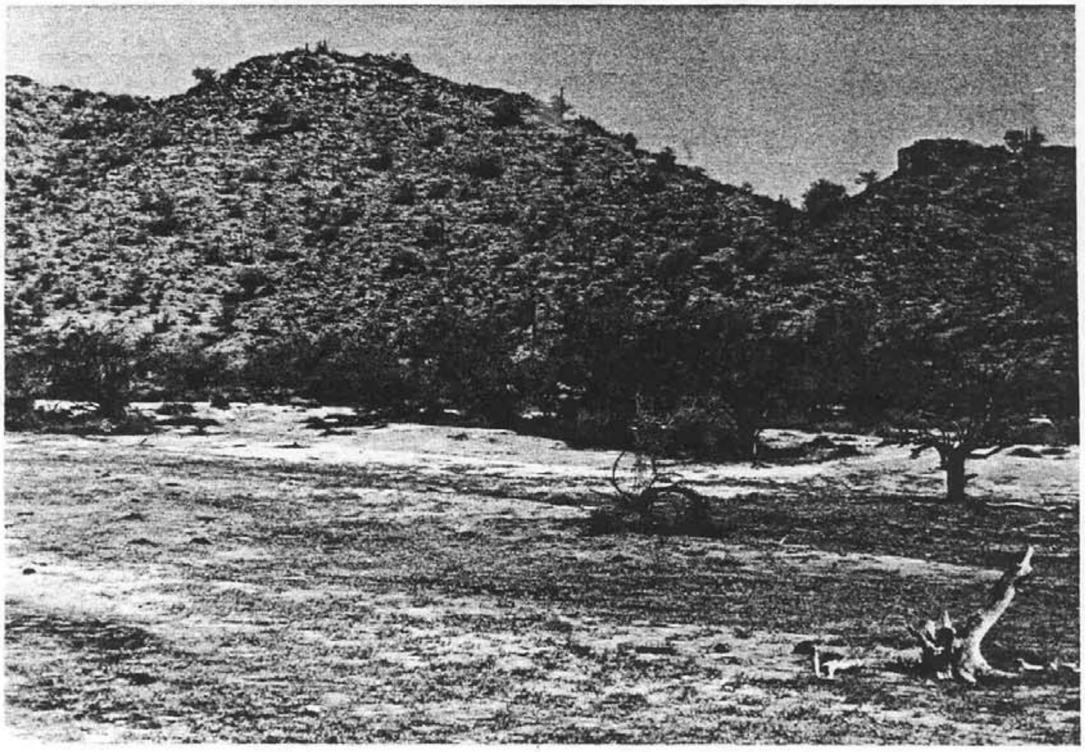


Figure 8a. (April, 1976) East side of the saline flat below Williams Spring. This is a closer view of part of the background of Figure 7. Saltgrass is in the foreground and the dark area on the left is a moist seep. The hillside in back is dominated by foothill paloverde, brittlebush, saguaro, ocotillo, and organ pipe cactus.

Figure 8b. (April, 1984) Saltgrass cover has increased to 80-90 percent and has spread up the bare slopes to the mesquite in the background. The tall clump at left-center is alkali sacaton. The seepweed among the mesquite have grown out from a severely hedged condition. No apparent change has occurred on the hillside in the background and most of the larger plants are recognizable as the same individuals from 1976.



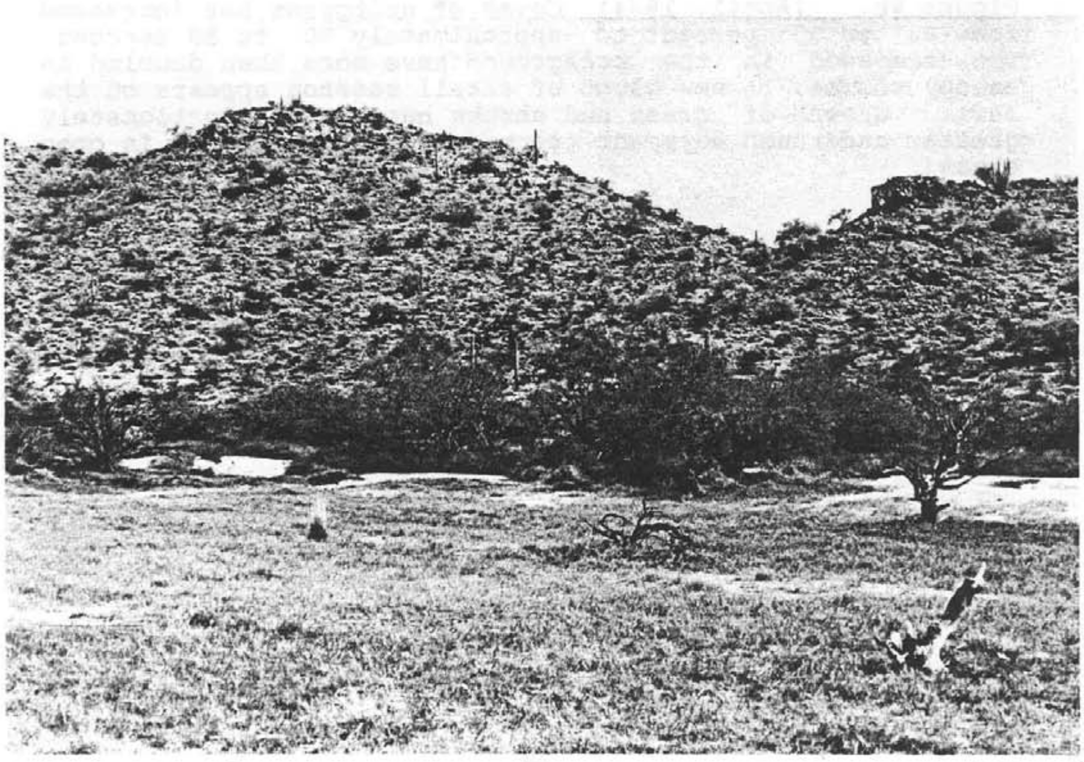
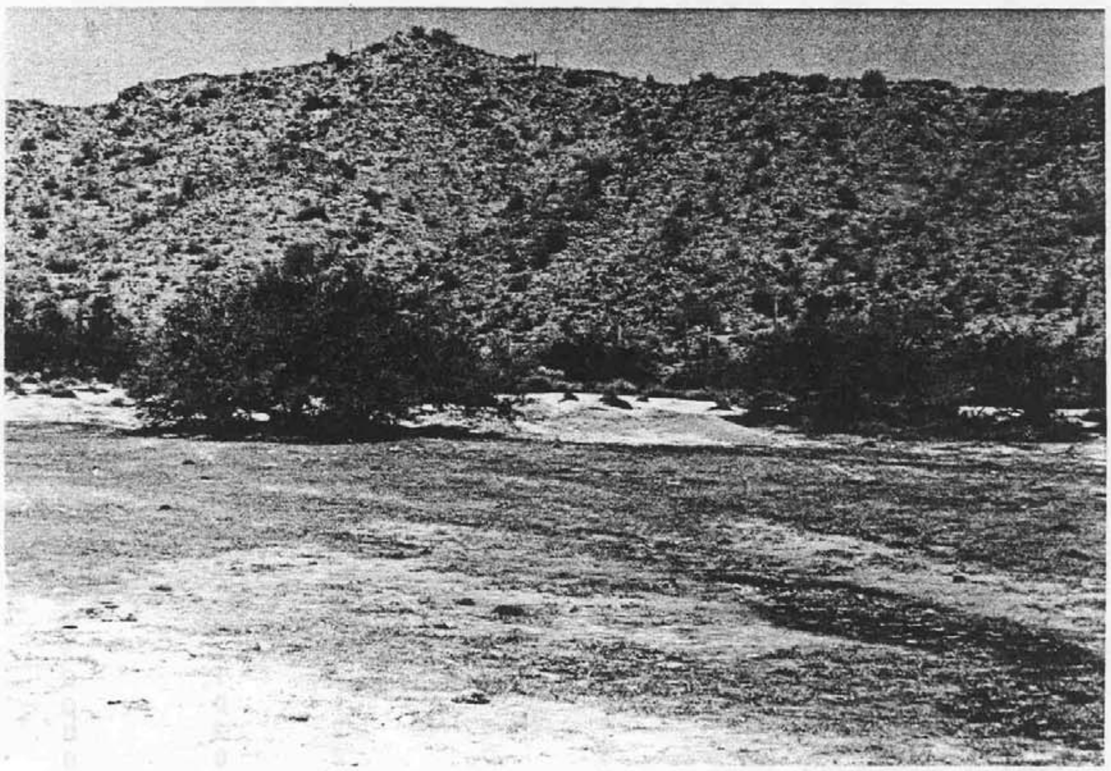
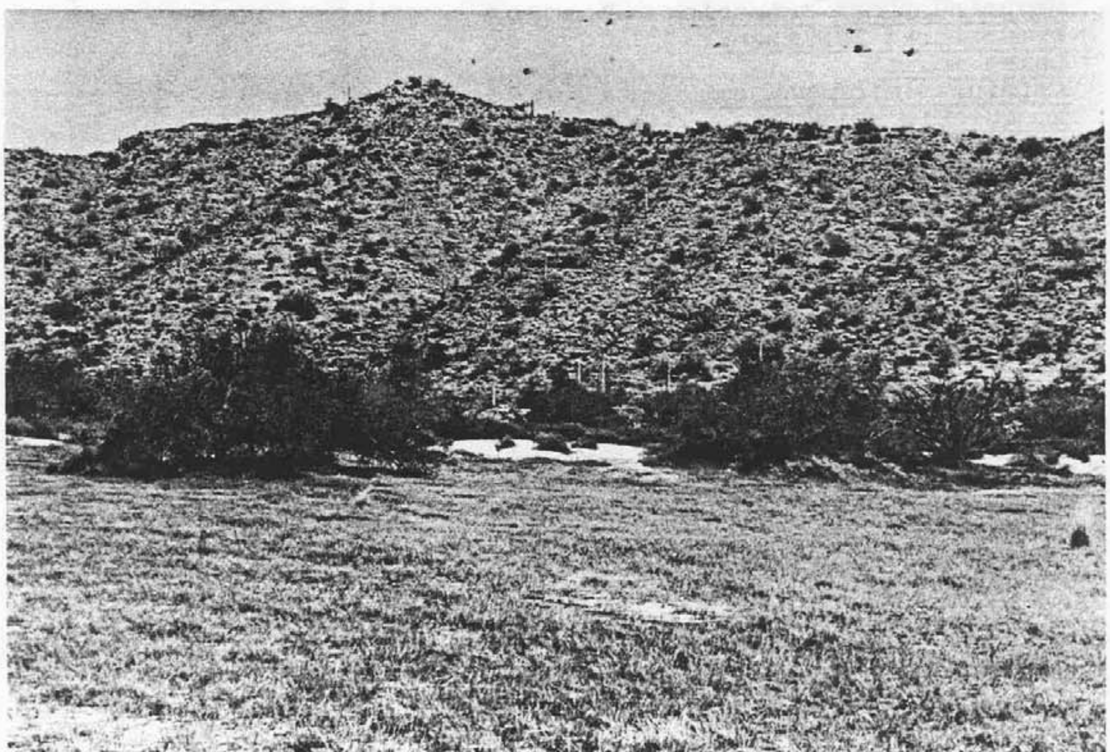


Figure 9a. (April, 1976) This photo is taken from the same location as Figure 8 and overlaps with it slightly to the north (the seep is now on the left). The area under the canopy of the middle mesquite tree is relatively open due to trampling by livestock seeking shade.

Figure 9b. (April, 1984) Cover of saltgrass has increased from 20 to 30 percent to approximately 70 to 80 percent. The seepweed in the background have more than doubled in canopy volume. A new clump of alkali sacaton appears on the left. Growth of grass and shrubs has been proportionately greater under and adjacent to mesquite trees than in open areas.





Burro Spring

Burro Spring is much smaller than Williams Spring, with lower flow and a more restricted area of mesic vegetation. The area of vegetation influenced by the spring is approximately 5 to 10 meters wide and 20 to 30 meters long. Williams, in comparison, has an expanse of several hundred meters across its terrace and salt flat. Burro has two main components the saturated spring source and the strip of moist soil extending down the wash below the source.

In 1976 the spring source at Burro was an open mud hole with sparse plant growth (Figs. 10-12). The adjacent stand of arrowweed (Tessaria sericea) and mesquite was kept open by the browsing of livestock. Herbaceous plants growing in the spring source and in the moist wash below the spring were, with the exception of bermuda grass, largely unrecognizable due to grazing.

By 1984 the spring source was grown in with native species, mainly bulrush, arrowweed and reed (Phragmites australis). The grassy strip along the moist wash, although still dominated by introduced bermuda grass and rabbitfoot grass (Polygon monspeliensis), is now wider. More species are evident, including some relatively uncommon herbs such as Centaurium calycosum. The once-open understory of the arrowweed mesquite thicket has completely filled in with marshy growth.

Although remarkable recovery from livestock disturbance has occurred at the spring in less than ten years, desertscrub on adjacent hillsides showed very little change over the same period of time. Most of the larger perennials are recognizable as the same individuals in the paired photographs. The greatest change appears to have occurred in the vigor and density of brittlebush (Encelia farinosa), which has increased in size and number on hills both northeast and southwest of the spring. However, because brittlebush has low palatability for livestock this increase is probably a response to the high rainfall of 1982-83, rather than a recovery from disturbance.

Agualita Spring

Aguajita Spring differs in one important respect from all the other springs of the Quitobaquito complex. Most of the springs occur high in the watersheds in which they are located, mostly within a few hundred meters of the crest of the watershed divides. Because only a small runoff area exists above the springs they are rarely if ever exposed to flooding and the disturbance flooding would have upon their vegetation. In contrast, Aguajita is located directly in the bottom of a major wash with a watershed of many square miles. As a result, Aguajita experiences heavy flooding almost yearly. Instead ofbeing choked with marshy vegetation as the other springs now are, its source is scoured clear of dense herbaceous vegetation byperiodic floods, resulting in a rivulet of free-flowing water several meters in length. Comparison of the water chemistry of Aquajita to the other springs indicate that it probably has a different source than the others (P. Bennett, pers. com.).

Figure 10a. (April, 1976) Looking up at Burro Spring from the wash below the spring. Note the hedged browse-line on the thicket of arrowweed and mesquite at the left rear. The plants on the hillside in the background are ocotillo, foothill paloverde, brittlebush and organ pipe cactus.

Figure 10b. (April, 1984) The spring has grown in with bulrush, arrowweed, and reed *Phragmites australis*. Grass in the arroyo below the spring has spread and is dominated by bermuda grass and rabbitfoot grass in the left foreground, both introduced species. Other herbaceous species not apparent in 1976 are *Centaurium calycosum*, spreading fleabane, slender poreleaf, and jackass clover. The increase in brittle bush on the hillside is due mostly to increase in the size of existing plants, though a few new individuals have appeared since 1976.

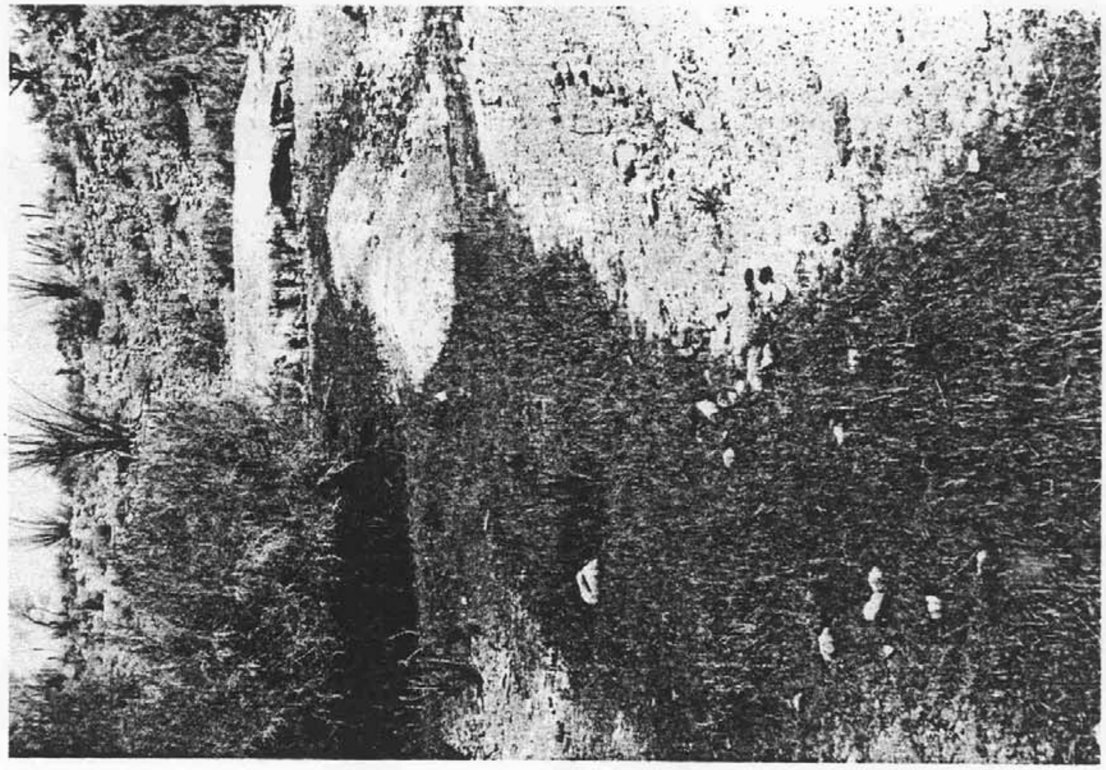
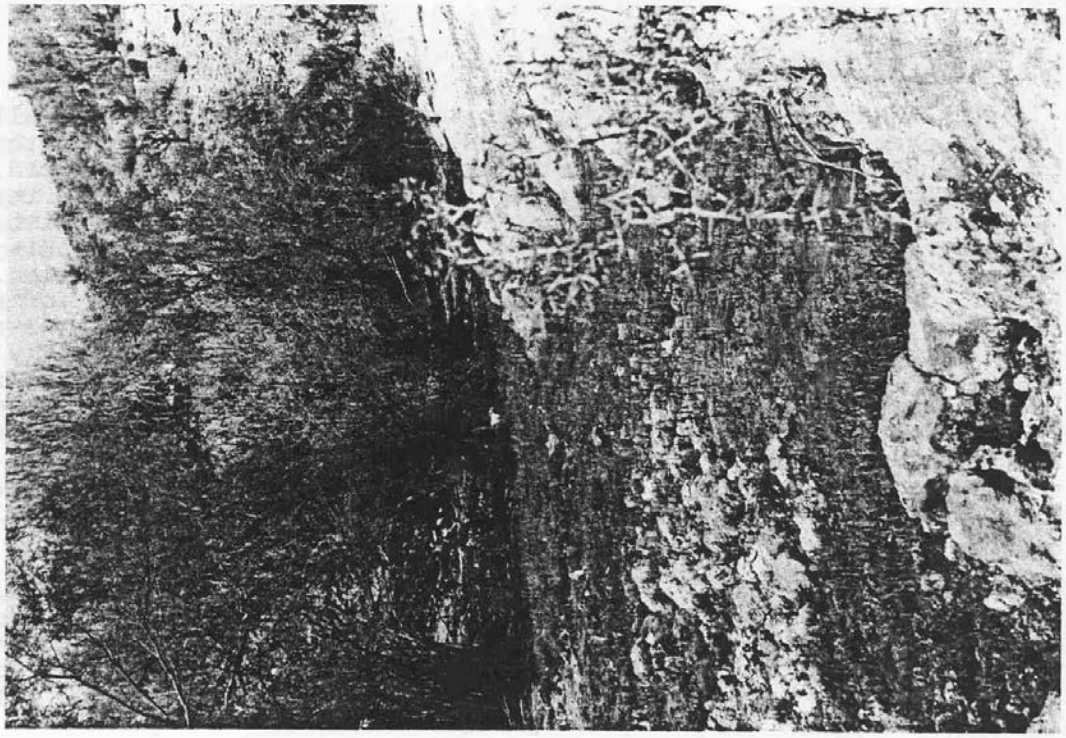


Figure 11a. (April, 1976) Looking southwest across Burro Spring from above the spring source. The thicket on the right is arrowweed and the grass in the arroyo is bermuda grass. The spring has been heavily trampled by livestock.

Figure 11b. (April, 1984) The person is standing on the bare mound at left center in the 1976 photo. The spring has grown in with bulrush, arrowweed, jackass clover, and <u>Phragmites australis</u>. An increase in the mesquite canopy is shown on the right. The hillside in back appears relatively unchanged with the exception of an increase in brittlebush.

Figure 12a. (April, 1976) The spring source at Burro Spring. The thicket in the rear is arrowweed with an overstory of mesquite which has been kept open by livestock seeking shade. The shrub in the right foreground is greythorn.

Figure 12b. (April, 1984) The spring is now choked with bulrush, arrowweed and Phragmites australis. Undergrowth in the thicket, now obscured by bulrushes, is so dense as to be virtually impenetrable.



Unfortunately no documentation, photographic or otherwise, is available for the Aguajita Spring source from the same time period as that for the other springs. The information presented here is from a series of three permanent plots that are located approximately 40 meters north of the spring, 0.8 km, and 2.4 km east of the spring.

All plots showed a marked increase in total cover between 1976 and 1984 (Table 1). The greatest change occurred in plot 200, closest to Aguajita Spring, where cover increased approximately six-fold (Fig. 13). Farther from Aguajita Spring the increase in vegetation cover is less, approximately two-fold in plot 2E1 and 1.5 times in plot 2E2. The increase in perennial cover was restricted largely to just a few species at all three plots, primarily seepweed, two species of saltbush (Atriplex polycarpa and A. linearis), white ratany (Krameria grayi), and bush muhly (Muhlenbergia porteri), all of which are palatable to livestock. Most of the less palatable species showed little or no change following livestock removal.

In plots where plants are clumped, the variance in mean cover was high and there may be no statistically significant difference between years even though the difference is biologically important. This is particularly evident in the case of species such as saltbush in which the flowers and fruit are the first part of the plant to be browsed, thus suffering a significant reduction in reproductive capability by a grazing intensity that may have a relatively small effect on species cover.

In spite of the large increase in cover on the plots, no comparable change in density was observed (Table 2). Seepweed experienced an apparent large decrease in density on the plot where it had the greatest increase in cover, primarily as a result of adjacent canopies intermingling as they expanded to the point that they were counted as single individuals. In general new species that are now present on the plots are fast growing herbaceous plants rather than woody species.

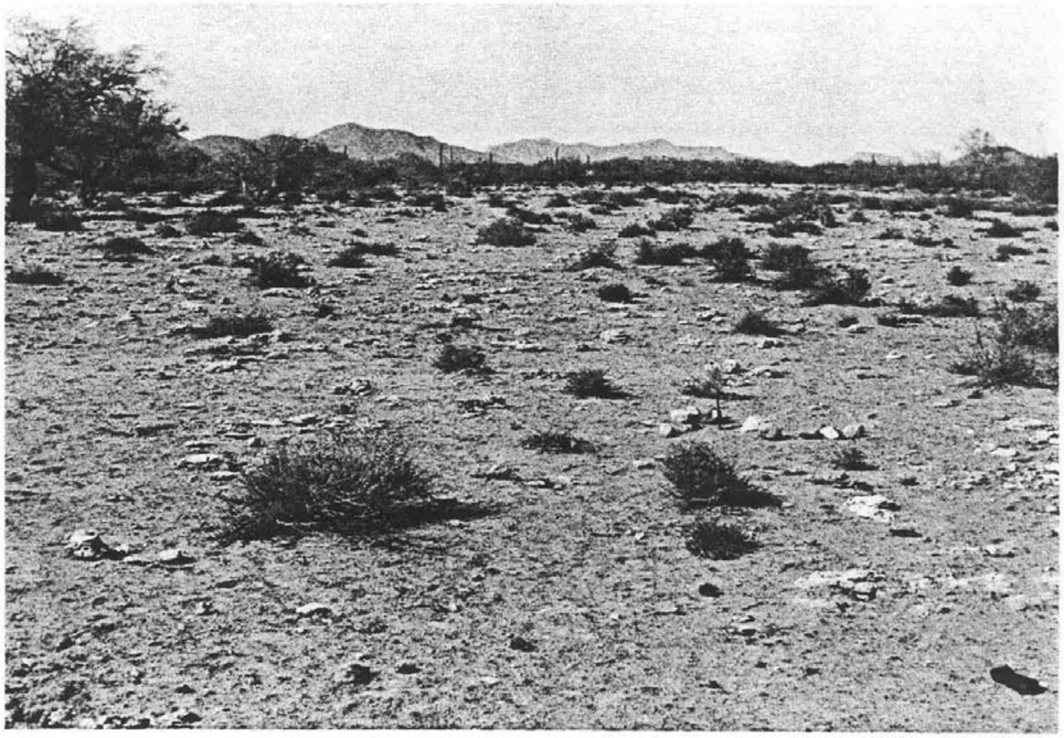
Table 1. Change in perennial plant cover (%) between 1975 and 1984 near Aguajita Spring.

Species	Plot 200 1975	Plot 200 1984	Plot 2E1 1975	Plot 2E1 1984	Plot 2E2 1975	Plot 2E2 1984
Suaeda torreyana	3.09	7.55*	0.98	2.11	0	0
Atriplex polycarpa	0.25	5.46**	4.80	12.26***	0.98	3.72*
Atriplex linearis	0.09	3.12***	1.34	2.97	1.02	0.93
Muhlenbergia porteri	0	2.72**	0	0.50	0	0
Larrea divaricata	0	0	0.98	1.61	6.84	5.87
Ambrosia deltoidea	0	0	2.41	2.69	1.91	5.72
Machaeranthera arizonica	0	0	0	0.70	0	0
Ambrosia dumosa	0	0	0	0	0.64	2.09
Opuntia stanleyi	0	0	0	0	0.27	0.48
Cercidium microphyllum	0	0	0	0	1.86	1.80
Fouquieria splendens	0	0	0	0	0.80	0.68
Olneya tesota	0	0	0	0	2.32	0
Krameria grayi	0	0	0	0	0	0.69
Total	3.43	18.85	10.51	23.11	16.64	21.98

* $p<.05$, $t>1.72$ ** $p<.01$, $t>2.53$ *** $p<.001$, $t>3.55$ df=20

Figure 13a. (December, 1974) Looking north from the road approximately 40 m northeast of Aguajita Spring. This is the location of plot 200. The browsed-hedged shrubs are seepweed and saltbush. The dark tree at the right rear is ironwood (Olneya tesota), but most of the others are mesquite.

Figure 13b. (April, 1984) The biggest change here is an increase in the size of seepweed and saltbush individuals (see also Tables 1 and 2). However, annual ground cover has also increased from almost nothing to approximately 50 percent. It is composed mostly of wooly plantain (Plantago insularis), mediterranean grass (Schismus barbatus), six-weeks needle grama (Bouteloua aristidoides), and globe mallow (Sphaeralcea sp.).



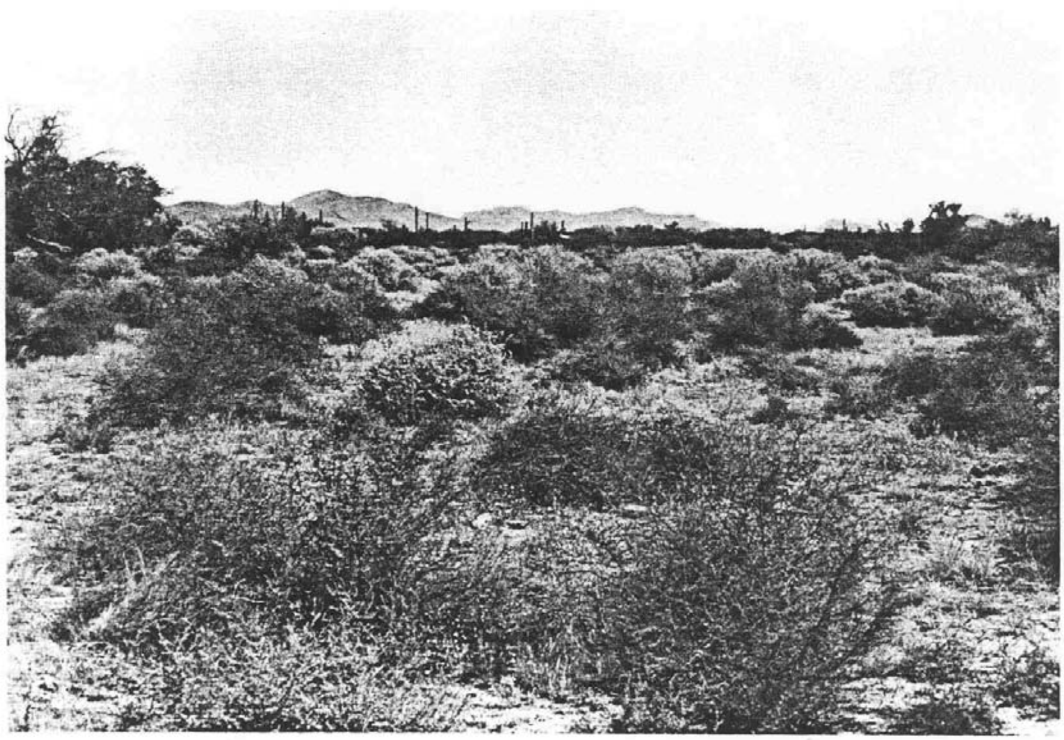


Table 2. Change in perennial plant density (individuals/0.1 ha) between 1975 and 1984 near Aguajita Spring.

Species	Plot 200 1975	Plot 200 1984	Plot 2E1 1975	Plot 2E1 1984	Plot 2E2 1975	Plot 2E2 1984
Suaeda torreyana	226	125***	11	12	0	0
Atriplex polycarpa	17	78*	137	150	54	103**
Atriplex linearis	50	61	90	127	73	95
Larrea divaricata	1	0	17	17	54	56
Ambrosia deltoidea	1	0	33	33	149	105
Ambrosia dumosa	0	0	1	3	82	72
Muhlenbergia porteri	0	84***	0	14*	0	0
Aristida spp.	0	3*	0	1	0	0
Opuntia stanleyi	0	0	2	2	6	14
Olneya tesota	0	0	1	1	2	1
Prosopis glandulosa	0	0	1	1	0	0
Echinocereus engelmanni	0	0	1	0	0	0
Opuntia leptocaulis	0	0	2	2	0	0
Opuntia fulgida	0	0	2	0	0	0
Lycium andersoni	0	0	1	1	0	0
Lycium parishii	0	0	0	2	0	0
Machaeranthera arizonica	0	0	0	24***	0	0
Hymenothrix wislizenii	0	0	0	2	0	0
Dalea mollis	0	0	0	1	0	0
Cercidium microphyllum	0	0	0	0	2	2
Fouquieria splendens	0	0	0	0	1	1
Mammillaria microcarpa	0	0	0	0	1	0
Krameria grayi	0	0	0	0	0	5
Total	295	351	299	393	424	467

* $p<.05$, $t>1.73$ ** $p<.01$, $t>2.55$ *** $p<.001$, $t>3.61$ df=18

<u>Conclusions</u>

The marshy and riparian vegetation surrounding each of the springs near Quitobaquito showed a substantial recovery in the 5 years since livestock was removed from the monument. This recovery took two forms: 1) Individual plants that had been severely browsed by livestock showed a dramatic increase in size and canopy cover. These plants may also have increased seed production since reproductive structures are towards the tops of the plants and therefore are browsed first by livestock. Increased seed production not only improves the likelihood of new individuals germinating but also increases the food resources of desert granivores such as pocket mice, kangaroo rats, ants, and birds. 2) New plants germinated and survived that previously may not have due to grazing and trampling by livestock. In most cases these represented species already present at the spring. In a few cases plants appeared on photos or in study plots that had not been found in that area before. These plants are almost all grasses such as, alkali sacaton and bush muhley, or scattered herbs such as <u>Centaurium</u> <u>calycosum</u>.

Total plant cover and especially the cover of palatable species such as seepweed and saltbush showed the most rapid and dramatic increase after livestock removal. This is a direct result of growing out of previously hedged individuals. The increase in plant density was not as dramatic or rapid as the increase in cover for two possible reasons. 1) It takes longer for plants to germinate and survive and 2) the increased cover of established individuals may inhibit germination and survival of seedlings. The recovery of desertscrub was not as dramatic as the recovery of the more mesic vegetation near the springs where some tree seedlings germinated and grew to over 4 m in 5 years. In desertscrub areas plants were less trampled than near the springs where cows congregated for shade and water and recovery was restricted to palatable species.

At Burro and Williams springs, which are high on the watershed, the spring source became choked with vegetation and the spring flow greatly reduced after livestock was removed. The spring source at Aguajita Spring remained open because it is located in a large wash which is lower on the watershed and often scoured by periodic floods. This indicates that the large pond at Quitobaquito Springs, which is probably not subject to periodic floods, would also be choked with vegetation under natural conditions. Since dense vegetation under these conditions would reduce the flow and availability of standing water, the Desert Pupfish may not have been present at Quitobaquito before the establishment of the man-made pond.

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