A FLORISTIC AND ECOLOGICAL STUDY OF THE PALM OASES OF JOSHUA TREE NATIONAL MONUMENT

(1969)

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by Lawrence T. Mc Hargue

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Introduction

The natural palm oases of the California desert constitute one of the rarest vegetation types in the United States. They are characterized by the presence of the California fan palm (*Washingtonia filifera*).[1] This species ranges from the areas of Twentynine Palms and of the Turtle Mountains of Riverside County, California, south through the Colorado Desert into Baja California. In addition there is one oasis of approximately 57 trees in the Kofa Mountains of western Arizona, the only palm oasis in that state. Henderson (1961) estimates that there are 11,000 native palms north of the Mexican border and an additional 18,000 palms within a distance of fifty miles of the international boundary. The palm oasis of the Turtle Mountains, the Oases of Mara and of Fortynine Palms mark the northernmost extension of the family Palmae in the Western Hemisphere. All three oases are north of the 34th parallel. Other oases occur at scattered locations in the Eagle and Chuckawalla Mountains. A concentration of oases exist along the San Andreas Earthquake Fault from Whitewater Canyon to a point due north of Indio. The bulk of the palms and oases in California are found at springs and seeps in canyons along the desert slopes of the San Jacinto, Santa Rosa, and Laguna Mountain Ranges from the vicinity of Palm

1. All nomenclature used follows Munz (1959, 1969).

Springs to the Mexican border. Palm Canyon is reported to have some 3000 palms (Henderson 1951), and it is thus the largest palm oasis to be found in the State of California.

Most of the palm oases in California have an uncertain future at best. Those oases which are privately owned are being threatened by the spector of impending urbanization and commercial development. Detailed plans have been formulated for the development of several of the large oases of the San Andreas Fault. Several have already been lost. Unfortunately, several of the threatened oases are among the finest examples of this rare vegetation type. As a result of the intensive emphasis on tourism and winter recreation, and the burgeoning population of the Coachella Valley, land values and consequent property taxes have risen so high that more intensive land utilization is being compelled. It appears that nothing short of war, total economic collapse, a declining population or some other as yet unforeseen catastrophe can halt this process. These factors threaten all privately held lands, and they may in time threaten those oases held by the state and federal governments as well.

Another source of danger to the vegetation of the palm oases comes from the high degree of visitor impact which is evident in many of them. Those oases which are readily accessible to the public show evidence of earth movement, soil compaction, trampled down plants (often prohibiting the reproduction of some species), damaged plants, accumulated trash and debris, and introduced weedy species. Increasing numbers of palms have been senselessly chopped down in recent years in the oases of the Coachella Valley.

Some longtime residents of desert areas claim that water levels have dropped during the past several decades. This has been attributed to long term drought (Tevis 1964) and sustained pumping of water for urban, agricultural and recreational use (Henderson 1963). Because the California fan palm is totally dependent on a shallow ground water table any reduction of water levels spells disaster for it.

A potential threat to the existence of present vegetational compositions of the palm oases is air pollution. The author has data which suggest that there may be some damage to the vegetation of the upper Coachella Valley. Smog has not been shown to be a definite factor affecting oasis vegetation at the present time, but desert areas are currently experiencing ever increasing amounts of smog, particularly in Desert Hot Springs, Palm Springs, Palm Desert and Indio. The author experienced a concentration of smog which was intense enough to be uncomfortable during a recent afternoon in Indio. Even if smog should become very heavy it will probably not eliminate the California fan palm itself, for they have withstood years of smog exposure in Los Angeles. Smog is likely to affect other species which normally occur in the oases.

California fan palm oases have been the subjects of very few past studies. The California fan palm has been noted as a characteristic species of the Colorado Desert (Coville and Mac Dougal 1903, Mac Dougal 1907, 1908, Parish 1930, Benson and Darrow 1954). Palm oases have been mentioned or briefly described by Mac Dougal (1908, 1914), Jepson (1910, 1922), Munz (1959) and Shreve and Wiggins (1964). The only quantitative study undertaken was that of Vogl and Mc Hargue (1966). That work will be referred to repeatedly in this study. In that investigation the oases of the San Andreas Fault from Whitewater Canyon to Indio, California were studied.

Palm Oases of Joshua Tree National Monument

Like some of the oases of the Coachella Valley, one of the oases of Joshua Tree National Monument has been well known for over a century. The Oasis of Mara ranks as one of the best known of all California fan palm oases. When Colonel Henry Washington led the survey party which laid out the San Bernardino Base Line in 1855, he noted the presence of a group of "cabbage palmettos" which were near a spring that was supposed to be permanent. A year later A. . Greene, deputy surveyor, visited the area while helping to lay interior lines from township corners. He indicated that the oasis was called Palm Springs. This is a curious notation, for he was only the third American who is known to have explored the area. However, the oasis was evidently known to at least a few Americans of whom we are unaware. The name Palm Springs persisted until the 1880's. The name Twentynine Palms was in common use by the 1870's (Miller 1969). Mining activity

LOCATION OF OASES

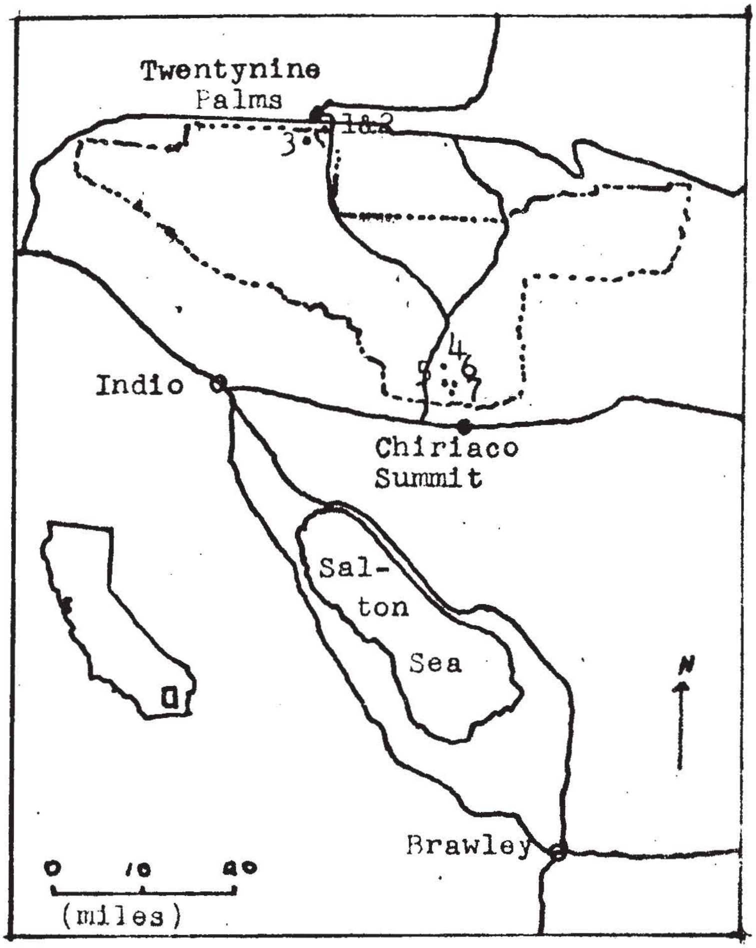

Fig. 1. Location of the Oases in Joshua Tree National Monument. The numbers refer to specific oases. Oases shown are Oasis of Mara (1), Twentynine Palms Inn (2), Forty-nine Palms (3), Cottonwood Spring (4), Lost Palms (5), Munsen Palms (6), and Victory Spring(7). The solid lines represnt roads and highways, and the dotted line represents the boundary of Joshua Tree National Monument.

many small palms, much cottonwood, and willow and honey mesquite. The water from the springs supported beds of tule and sedge (probably Scirpus acutus or perhaps another Scirpus sp., and Typha sp.). Today the sedges and tules are gone, and so are the cottonwoods. The honey mesquite and willows (Salix lasiolepis) have been greatly reduced in importances by falling water tables and fire. The description given of the vegetation of the eastern half is similar to that which exists today.

There has been another change in the physical conditions in the Oasis of Mara as well. The water table has dropped during the last several decades. There was a spring of water there in 1855 (Miller 1965), and Carter (1937) describes the eastern portion of the oasis as having springs and water holes and the western part of the oasis as having numerous springs and two pools of open water. In addition there were five acres of grassy swamp which at one time were used to pasture animals. Today there are no open springs, water holes, or pools, and no vegetation that can truly be described as grassy swamp. Ground water levels in the oasis appear to be highest beneath the patches of Elymus triticoides where the water table may approach three or four feet of the surface. Robert van Lahr, the owner of Twentynine Palms Inn, told me that water levels in his wells have dropped markedly since 1939. He attributes much of the drop in water tables to the heavy pumping which has taken place to provide water for urban and domestic use in the Twentynine Palms Valley. This drop in water tables is well correlated with the decrease in the measured rate of flow of springs in Joshua Tree National Monument since 1948. Monument records show marked decreases in the flow of springs and even in the number of springs themselves. If the water table continues to drop in the future as it has during the last several decades, then the future of the oases of the Monument appears bleak.

Carter (1937) noted that the Oasis of Mara was interrupted near its center to form two separate parts. The eastern half of the oasis is part of Joshua Tree National Monument, and the headquarters building is located on its eastern end. The western half of the oasis is privately owned and is the site of the Twentynine Palms Inn. The two halves are quite different in several respects. The western half is more mesic than the eastern half. There is a great deal more area that is covered by grass. The western half has been burned during the last few years while the eastern half has not burned in many decades. As a result the other arborescent species have been eliminated or severely reduced in importance. The understory shrubs have also been reduced in importance. In contrast the eastern half is overgrown with shrubby and aborescent species which in places compose an impenetrable mass of vegetation. For these reasons I have decided to treat the two halves of this oasis as if they were separate. The western half will be called the

Twentynine Palms Inn Oasis, and the eastern half the Oasis of Mara. I feel that this is not a completely artificial division. If it was then, both halves would have burned when Twentynine Palms Inn Oasis burned. Once an oasis fire is burning out of control it is exceedingly difficult to extinguish.

Both of these oases are created by the Pinto Mountain Fault (Miller 1957, Rogers 1961). Water percolating through the ground encounters relatively impervious strata along the Fault line and is forced to the surface. A fault scarp a few feet high is present in these oases. The Oases of Mara and Twentynine Palms Inn are located on alluvial deposits. Soils there are deep and fine grained. It proved to be relatively easy to dig down to ten feet using a soil auger of 4" diameter. The elevation of the oases is about 1960 feet, and they are in section 33, R9E, T1N.

All of the other oases are located in different terrain. Fortynine Palms is in a narrow, rocky canyon where soils are thin, and large boulders are found at scattered points within the oasis itself. This oasis is associated with a small fault, and the base rock at Fortynine Palms is Palms quartz monzonite (Rogers 1961). There is a small pool at the upper end of the oasis. A group of palms grows on the east side of the canyon about 100 feet above the canyon bottom. Some palms grow among the boulders on the canyon bottom, and another group is found on a slope where the canyon is somewhat wider. The canyon bottom has a tangle of dense vegetation.

Below the palms the canyon bottom is overgrown with a dense stand of *Salix exigua*. Of all of the oases only Lost Palms is as enjoyable a place to visit. The elevation of Fortynine Palms is about 2800 feet, approximately three and one half miles southeast of the intersection of Adobe Road and Twenty-nine Palms Highway in Twentynine Palms.

Lost palms is also located in a narrow canyon. Its elevation ranges from about 3050 feet to about 3400 feet with the largest concentration of palms being found at about 3200 feet. It is located in section 29,R10E, T5S. In the lower part of the oasis the palms and other vegetation, which is dependent on a permanent supply of water, are found primarily on the bottom of the canyon. The wash bottom is narrow, and in places is devoid of vegetation where it has been scoured. The canyon bottom supports large populations of *Muhlenbergia rigens* tussocks, *Salix exigua*, *Juncus acutus* var. *sphaerocarpus*, and *Baccharis sergiloides*. The physical setting of this oasis and several of the major species occurring there can be seen in the photographs in the back of the paper. In the upper portion of the oases there are palms growing at seeps on the rocky slopes of a side canyon on the east side of Lost Palms Canyon.

Another oasis located in a narrow, rocky canyon is Munsen Palms named for the canyon in which it occurs. According to B Bill Dengler, the ranger at the Cottonwood Spring ranger station, Munsen Canyon is erroneously called Lost Palms Canyon on the U. S. G. S. Hayfield 15 minute quadrangle. Experience proved him to be correct. This oasis has a developed spring which is used as a source of water for the small settlement of Chiriaco Summit on Highways 60-70 and Interstate 10 several miles to the south, outside the boundary of Joshua Tree National Monument. In many respects Munsen Palms is similar to Lost Palms. The area of the oasis is much smaller, however. The oasis is also more xeric than Lost Palms. There is a [illegible] area on the southeast side of the oasis which possesses the same species which are commonly found washes or the area, but in much greater densities. There is a dense clump of palms in a small side canyon. The elevation of the oasis is approximately 3300 feet, and it is located in sections 20 and 21, R-12E and T5S.

Another oasis in the same area is Victory Spring. This is a very small oasis, having only two living palms. It is quite xeric, and most of the species growing there are quite common in washes and on slopes in the same general area. This spring, too, has been developed as a water source for Chiriaco Summit. It is located in section 29, R12E, T5S, at an elevation of 2700 feet.

Another oasis in the National Monument is a creation of man. Cottonwood Spring has been used as a source of water since the late nineteenth century. It has been developed so that a permanent trickle of water flows to the surface of the ground. Around the source of water there is a small grove of palms which contains most of the palms of the oasis. The oasis is located in a gulch or canyon with a sandy bottom. Along the east side of the canyon is a slope which supports many individuals of species which are common in the immediate area. However, densities are higher, as is the case with a xeric area of Munsen Palms. The lower portion of the oasis has a high water table as evidenced by one California fan palm, and numerous bushes of Baccharis sergiloides. Visitor impact is seen everywhere in this oasis. It was used as a camp ground until a few years ago, and it has been the site of human habitation (Miller 1965). Evidence of this is seen in the two introduced species, Phoenix dactylifera and Cynodon dactylon. The Phoenix appears to have been planted. This oasis is found at an elevation of 2950 feet in section 14, R11E, and T5S.

Cottonwood Spring, Lost Palms, Munsen Palms and Victory Spring all are located in areas in which the bedrock is Mesozoic granite (Jennings 1967).

In addition to the oases discussed above there are two other locations where palms occur, or where they are reported to occur. There is one palm in the canyon below Victory Spring. If the palm had been the same distance away from any other oasis it would have been included within it, but due to the very small size of the oasis this palm was excluded. Another palm has been reported from a canyon behind Fortynine Palms. On the map of Rogers (1961) it is called Lone Palms. Several people on the Joshua Tree National Monument mentioned Lone Palm. There seems to be some doubt about its present existence. Because of the difficulty of access I was unable to verifty its existence or to visit it.

Field Methods

During the course of the study all of the oases were visited at least once. The Oasis of Mara was visited six times. This was considered necessary because of its greater areal extent and its importance in terms of its public image as the palm oasis par excellence. Lost Palms, Victory Spring, Fortynine Palms, and Twentynine Palms Inn Oasis were each visited twice. Munsen Palms and Cottonwood Spring were visited once.

A species presence list was made at each oasis. Intensive collecting in the oases would undoubtedly add more species to the lists. However, all of them would be minor in terms of their importance in the vegetation. Visits at different seasons would also reveal a few more species. The expenditure of time and effort required to significantly expand the species presence lists was felt to be too great to make the effort worthwhile. The lists have been compiled in Appendix A.

Each oasis was sampled using 100 ft. line intercepts and adjacent 1/40th acre quadrats of 9.8 by 111 ft. A total of 41 samples were used to sample the vegetation of the oases. Because of the critical relationship between ground water tables and the distribution of vegetation the normal procedure of taking randomly placed samples could not be followed. Instead they were placed so that each of the vegetational associations of the oases were sampled with a number of line intercepts and quadrats roughly proportional to the area occupied. The

Oasis of Mara was sampled using 16 line intercepts and adjacent quadrats. The other oases and the number of line intercepts and adjacent quadrats were as follows; three in Twentynine Palms Inn, six in Fortynine Palms, four in Cottonwood Spring, seven in Lost Palms, four in Munsen Palms, and one in Victory Spring.

The data from the line intercepts was used to compute absolute percent cover, or dominance, and relative dominance. All the woody based perennials within the 1/40 acre quadrats were counted by size class. Size class I consisted of seedling and very young plants. Size class II was composed of plants which fell into the normal range of height and breadth for each species. Those plants of exceptional size were included in size class III. The great bulk of the individual plants encountered fell into size class II. The California fan palm itself was treated somewhat differently with respect to size class. The method of treatment used with palms will be found in the section on palm reproduction. The limits of the size classes were determined by the experience of the observer. This data was obtained for the purpose of gaining information regarding the successional position and the reproductive status of the species encountered. Both absolute and relative density were yielded from the data derived from the quadrats.

The relative dominance and the relative density were combined for each species to form importance values (hereafter referred to as IV's). The IV's were then used for most of the floristic analyses.

In addition to the preceding information two other types of data were gathered. Any man-caused disturbance of natural vegetation was noted. Compared to the oases of the San Andreas Fault disturbance is relatively light. Several borings were made in the Oasis of Mara with a soil auger. Two of these attained a depth of ten feet.

Floristic Analysis

Several types of analysis were used to elucidate the vegetational relationships of the seven oases included in the present study. Some of these were based on quantitative data obtained from the line intercepts and adjacent quadrats. Other methods were used in which the primary source of information was derived from the species lists. In several instances both types were used for the same type of analysis.

<u>Prevalent Species</u>. The mean number of species per oasis was determined from the presence lists. Then the species were arranged in decreasing value according to their presence values beginning with the highest values. A group of the most widely distributed species equal in number to the mean number of species per oasis were designated as prevalent species.

This procedure is the same as that used by Curtis (1959). In addition I have introduced one modification of his method. His data was based on large numbers of stands. Inasmuch as the present study is really based on very few stands, there are a number of species which possess identical presence values. These have been ranked by their average IV's per oasis. The ranked prevalent species are shown in Table I along with their average IV per oasis and a weighted average of IV which was computed in terms of IV per individual sampling unit.

An indication of the degree of the oases' vegetational diversity is found in the number of prevalent species which occur in a limited number of oases. Only one species, the

California fan palm itself, is found in all seven of the oases, and an additional species is found in six oases. Four species are found in five of the oases, 11 species in four oases, and eight of the prevalent species were confined to only three of the oases.

A more precise measurement of the homogeneity of the stands is afforded by the use of the index of homogeneity. This value is derived by comparing the sum of the presence of the prevalent species with the sum of presence of all species (Curtis 1959). This yielded a value of 55.5%. This value indicates a large degree of diversity within the stands, but it is not excessively low, and it is similar to many other values derived from a variety of different plant communities in other parts of the United States.

It is obvious from Table I that some species are widely distributed in these oases, but they never constitute a major portion of the vegetation in any of them. This is certainly true of Acacia greggii, Simmondsia chinensis, Lotus rigidus, Sphaeralcea ambigua, and others. Another group of species may be very important in one or several oases and be totally absent in the rest. Suaeda torreyana, Elymus triticoides, Muhlenbergia rigens, Salix exigua, Atriplex canescens, and Populus fremontii are examples of such species. The former group usually consists of those species which are commonly found in washes or desert slopes surrounding the oasis. The latter group are usually species which are confined to the moist soils of the oasis itself.

Table I. Prevalent Species

Species	% presence	avg. IV per oasis	avg. IV per unit sample
Washingtonia filifera	100.0	54.5	35.8
Prosopis juliflora var. torreyana	85.7	10.9	23.4
Pluchea sericea	71.4	3.6	7.1
Acacia greggii	71.4	2.4	1.5
Simmondsia chinensis	71.4	0.4	0.1
Phorodendron californicum	71.4	0.1	0.2
Baccharis sergiloides	57.1	17.9	12.8
Gutierrezia microcephala	57.1	8.2	1.9
Salix lasiolepis	57.1	3.8	5.7
Isomeris arborea	57.1	3.7	2.9
Prunus fasciculata	57.1	3.7	2.2
Zauschneria californica ssp. latifolia	57.1	2.6	3.3
Coleogyne ramosissima	57.1	2.0	1.8
Lotus rigidus	57.1	2.3	0.9
Sphaeralcea ambigua	57.1	1.6	0.5
Eriogonum fasciculatum var. flavovirede	57.1	1.0	0.7
Muhlenbergia rigens	42.9	19.1	19.9
Salix exigua	42.9	9.0	9.4
Atriplex canescens	42.9	4.0	5.5
Distichlis spicata	42.9	3.1	3.7

Table I. Prevalent Species (cont.)

Species	% presence	avg. IV per oasis	avg. IV per unit sample
Populus fremontii	42.9	1.7	2.8
Yucca whippleyi	42.9	1.6	0.4
Viguiera deltoidea var. *parishii*	42.9	1.2	0.8
Brickellia arguta	42.9	0.[illegible]	0.6
Andropogon barbinodis	42.9	0.3	0.4
Lycium andersonii	42.9	0.3	0.2
*Suaeda torreyana**	28.6	11.5	21.2
*Elymus triticoides**	28.6	11.2	4.7

*These two species are not prevalent species, yet they were included in this table because of their extreme importance in the vegetation of the Oases of Mara and Twentynine Palms Inn.

"Endemic" and "rare" species

Each of the oases considered in this study has included in its flora at least one perennial species which does not occur in any of the others. These have been termed "endemics". This does not mean that the entire natural distributions of these species are confined to one oasis. It only means that they only appeared on the species presence lists of one oasis. Some of these species are quite common or even abundant elsewhere. A list of these "endemic" species and their importance values is found in Table II. Some of these species are common in the surrounding desert areas. Others (such as *Adantium capillus-veneris* which is most decidedly not!) have very spotty distributions in desert areas. In some cases many miles would separate individual populations.

A number of species occur in only two oases. These were termed "rare" species. These too are often quite common in other areas, though they only appeared on the species presence lists twice. The upper limit of the number of appearances permissible for "rare" species was easily determined because the prevalent species were found in as few as three oases.

It will be noted that the distributions of both the "Endemic" and the "rare" species parallel physical conditions in the oases. Both the Oases of Mara and of the Twentynine Palms Inn are rather alkaline. Of the "endemic" and "rare"

Table II. Endemic Species by Oasis

Oasis	Species	% Cover	IV
OASIS OF MARA			
	Apocynum cannabium var. *glabberimum*	-	-
	Atriplex lentiformis	0.3	0.6
	Cucurbita palmata	-	-
	Datura meteloides	-	-
	Glycyrrhiza lepidota	0.6	2.9
	Opuntia echinocarpa	0.1	0.4
	Phragmites communis var. *berlandieri*	3.3	5.8
	Prosopis pubescens	1.3	3.1
	Sporobolus airoides	0.1	1.4
TWENTYNINE PALMS INN OASIS			
	Anemopsis californica	-	-
	Heliotropum curassavicum var. *oculatum*	-	-
FORTYNINE PALMS			
	Adantium capillus-veneris	1.2	1.6
	Bouteloua curtipendula	-	-
	Equisetum hymale var. *robustum*	13.0	15.8
	Eriophyllum sp. (?)	-	0.8
	Fagonia californica	0.2	0.8
	Juncus macrophyllus	-	-
	Typha latifolia	-	-

Table II. Endemic Species by Oasis (cont.)

Oasis	Species	% Cover	IV
COTTONWOOD SPRING			
	Mirabilis froebelii	0.4	4.3
LOST PALMS			
	Dudleya saxosa ssp. *aloides*	-	-
	Equisetum funstoni	-	-
	Galium stellatum var. *eremicum*	-	-
	Hofmeistra pluriseta	-	-
	Juniperus californica	-	0.2
	Lepidium fremontii	-	-
	Stanleya pinnata	-	-
MUNSEN PALMS			
	Quercus turbinella	-	-
	Stillingia paucidentata	-	0.6
VICTORY SPRING			
	Lepidospartum squamatum	0.8	4.4
	Cassia armata	-	3.8

Table III. Rare Species by Oasis

Oasis Combinations	Species	IV in first oasis	IV in second oasis
TWENTYNINE PALMS INN AND OASIS OF MARA			
	Atriplex polycarpa	24.6	1.2
	Elymus triticoides	46.6	3.2
	Haplopappus acradenius	8.5	-
	Juncus balticus	0.2	0.7
	Suaeda torreyana	43.3	32.2
FORTYNINE PALMS AND LOST PALMS			
	Epipactus gigantea	0.4	0.1
	Machaerantha tortifolia	-	-
	Rhus trilobata	-	-
FORTYNINE PALMS AND COTTONWOOD SPRING			
	Cynodon dactylon	-	-
LOST PALMS AND COTTONWOOD SPRING			
	Krameria grayi	-	-
	Yucca schidigero	-	-
COTTONWOOD SPRING AND MUNSEN PALMS			
	Cercidium floridum	-	-
MUNSEN PALMS AND VICTORY SPRING			
	Convolvulus longipes	-	-

Table III. Rare Species by Oasis (cont.)

Oasis Combinations	Species	IV in first oasis	IV in second oasis
	Echinocereus engelmannii	-	-
	Encelia farinosa	0.3	-
	Hyptis emoryi	3.0	1.9
LOST PALMS AND MUNSEN PALMS			
	Juncus acutus var. *sphaerocarpus*	3.8	0.6

species found on these two oases *Prosopis pubescens*, *Sporobolus airoides*, *Atriplex lentiformis*, *Phragmites communis* var. *berlandieri*, *Anemopsis californica*, *Heliotropium curassavicum* var. *oculatum*, *Elymus triticoides*, *Haplopappus acradenius*, *Juncus balticus*, and *Sueada torreyana* are all known to require or at least be tolerant of alkaline conditions (Munz 1959, Mason 1957, Vogl and Mc Hargue 1966). I can only conclude that *Apocynum cannabium* and *Glycyrrhiza lepidota* are also tolerant of alkalinity as well. The future of *Glycyrrhiza* on the Oasis of Mara appears to be endangered by falling ground water levels. A soil sample taken to a depth of four feet in the midst of the *Glycyrrhiza* population showed no significant amount of soil moisture. Most of the plants have died, presumably due to a lack of water. It is likely that this species will soon disappear from the flora of the Oasis of Mara. Most of the preceding "endemic" and "rare" species are known to prefer the deep, stable soils that these oases do possess.

Most of the "endemic" and "rare" species of Fortynine Palms Oasis reflect the very hydric conditions to be found in that oasis. *Adantium capillus-veneris*, *Equisetum hymale* var. *robustum*, *Juncus Macrophyllus*, and *Typha latifolia* are all hydrophytic species. Another species which is certainly hydrophytic is *Epipactus gigantea*. In keeping with the general character of the two oases where *Epipactus* is found, the species is much more important at Fortynine palms than in Lost Palms.

In addition to *Epipactus gigantea* two other "rare" species are found in both Lost Palms and Fortynine Palms, *Rhus trilobata* and *Machaerantha tortifolia*. The latter species is quite common on rocky sites throughout the area. Since both oases are located in rocky canyons, it is not surprising that this species should be found there. The "endemic" species found at Lost Palms are common on rocky and/or dry slopes in the area. One exception is *Equisetum funstoni*. This is certainly hydrophytic. It came as a surprise to me to find that this was not the same *Equisetum* species found at Fortynine Palms. Strobili were present on the plants, though the colony does not appear to be doing very well. The future appears bleak for this species in Lost Palms.

With several exceptions all the other "rare" and "endemic" species in the remaining oases are normally found in the area, and they happen to find favorable sites within the oases. One individual of *Quercus turbinella* was found at Munsen Palms. This species is frequently found at higher elevations in the area, but it is not common at elevations as low as 3000 ft. *Cynodon dactylon* is an introduced species. It has become widely naturalized in the Coachella and Imperial Valleys. *Juncus acutus* var. *sphaerocarpus* is found in moist saline places in cismontane southern California and at alkaline seeps below 2000 ft. in the Colorado Desert. Since both these oases are significantly above 2000 ft. in elevation, and because they are in the Eagle Mts., this may be an extension of range for this species.

Family Analysis. The species presence lists from each oasis were analyzed to determine which plant families are most important in the vegetation of the oases. The contribution of each important plant family to the flora of each of the oases was first determined on the basis of presence alone. Then the cover and the IV for each of the families was also determined. The figures for each family and oasis are found in Appendix B. A summary of the data for all oases is found in Table IV. Other families were represented in the total flora of the oases, but they each represent such a small portion of the flora that they are not significant in this analysis.

The family Palmae can be seen in Table IV to be the most important single family in terms of cover even though it is monospecific in the study area. However, it was not the most important family in Lost Palms, Cottonwood Spring, or the Oasis of Mara, and it is rivaled in Fortynine Palms. The Gramineae is a major family, and it is by far the most important family at Lost Palms. This family has attained its great importance largely through the presence of *Muhlenbergia rigens* at Lost Palms, Munsen Palms, and Fortynine Palms, and *Elymus triticoides* and *Distichlis spicata* at the Oases of Mara and Twentynine Palms Inn. The family Chenopodiaceae is a leading family within the oases by virtue of large populations of *Atriplex polycarpa* and *Suaeda torreyana* at the Oases of Mara and Twentynine Palms Inn and a large population of *Atriplex*

Table IV. Most Important Plant Families

Family	Cover per Unit Sample	IV per Unit Sample	Avg. % of Flora per Oasis.
Palmae	19.8	54.5	5.0
Gramineae	18.7	31.7	8.2
Compositae	7.7	31.2	24.4
Chenopodiaceae	8.4	30.6	4.7
Salicaceae	9.9	17.9	5.8
Equisetaceae	1.9	2.3	0.9
Capparidaceae	0.4	2.9	2.1
Rosaceae	1.5	2.3	3.0
Malvaceae	0.1	1.6	2.5
Polygonaceae	-	0.7	2.3
Agavaceae	-	0.4	3.0

canescens in the unstable wash bottom at Cottonwood Spring. The family Leguminosae attains its high importance primarily because of the very large population of *Prosopis juliflora* var. *torreyana* (honey mesquite) at the Oasis of Mara. *Salix exigua* and *Salix lasiolepis* are the species responsible for giving the family Salicaceae its position of importance. The former species is very important in the vegetation of Fortynine Palms, Lost Palms and Munsen Palms. The latter species is found at Lost Palms, Fortynine Palms, and the Oases of Mara and Twentynine Palms Inn. *Isomeris arborea* is the only representative of the family Capparidaceae. The Compositae are represented by more species than any of the other plant families. This is consistent with the large number of Compositae which do occur in desert regions of North America. The most important single species of this family are *Baccharis sergiloides* and *Pluchea sericea*. *Baccharis sergiloides* occurs in Fortynine Palms, Lost Palms, Munsen Palms, and Cottonwood Spring, while *Pluchea* was found in all oases except Munsen Palms and Victory Spring. The family Juncaceae is represented by *Juncus balticus* and *Juncus acutus* var. *sphaerocarpus* in those oases shown in Table III. *Prunus fasciculata* and *Coleogyne ramosissima* are the two members of the family Rosaceae which appeared in the flora of the oases. This family is poorly represented in desert areas as a whole, though a number of species are well adapted to the arid conditions found on our deserts and in the Great Basin. Eriogonum fasciculatum var. flavovirede is the only important member of the Polygonaceae found in the oases, though there are some herbaceous annual species present, and Eriogonum inflatum is certainly present in the area and may well occur in some of the oases. The families Malvaceae and Agavaceae are represented by one and two species respectively. These three species (Sphaeralcea ambigua, Yucca whippleyi, and Yucca schidigera) are quite common on slopes and in canyons in the surrounding rocky mountains.

It can be readily seen that though a family may be well represented in the flora of the oases, this does not necessarily mean that it will constitute a large portion of the vegetation. This is best illustrated in the case of Compositae. The average percentage of composites in the floras of the oasis is 24.4, the highest figure for any family. Yet in contrast the IV figures for the family are lower than those of three other families, and the compositae coverage figures are exceeded by four other families. Family representation by numerous species it is no guarantee that the coverage and IV figures will be high.

In contrast the family Palmae is represented by one native species, and yet its IV's and coverage values are quite high. The families Salicaceae and Chenopodiaceae are represented by only three and four species respectively, yet they both have high IV's and coverage.

Floristic Comparison of Oases.

Several different approaches were used to compare the vegetation of the seven oases included in this study. They included methods based on both qualitative (simple presence or absence) and quantitative data derived from the sampling of the oases. Originally it had been hoped that these oases could be divided into three zones (oasis proper, desert-oasis ecotone, and hydric zones) as had the oases of the San Andreas Fault (Vogl and Mc Hargue 1966). This proved to be impractical for two reasons. Only one oasis, Fortynine Palms, possesses any substantial area which could be considered truly hydric. Even that zone could only be sampled using much smaller quadrats and shorter line intercepts. A second problem became apparent in using this approach on the oases of the Joshua Tree National Monument. Only the Oases of Mara and Twentynine Palms Inn possess a clearly defined desert-oasis ecotone, though individual samples from Cottonwood Spring, Munsen Palms, and perhaps Lost Palms and Victory Spring would be considered as being in this zone. Since the number of hydric and desert-oasis ecotone samples from most of the oases is so limited, it was felt that there was an insufficient amount of data to warrant such an analysis.

The species presence of each of the oases was compared with that of all other oases to yield Jaccard's Index or the coefficient of community. This was obtained by dividing the number of species common to two oases by the total number of species found in both oases. This was first proposed

Table V. Coefficient of Community

Oasis	Oasis*						
	OM	291	49P	CS	LP	MP	VS
Oasis of Mara	-						
Twentynine Palms Inn	40.0	-					
Fortynine Palms	16.0	15.0	-				
Cottonwood Spring	19.5	12.1	29.2	-			
Lost Palms	10.2	8.2	50.0	27.3	-		
Munsen Palms	7.8	4.8	42.8	30.7	52.2	-	
Victory Spring	2.2	3.0	19.0	25.0	28.2	32.4	-

* Key to table: OM stands for Oasis of Mara, 29I for Twenty-nine Palms Inn, 49 for Fortynine Palms, CS for Cottonwood Spring, LP is Lost Palms, MP for Munsen Palms, and VS for Victory Spring.

In this table the flora of each of the oases is compared to that of every other oasis. The coefficient of community is derived by dividing the number of species possessed in common by the total number of species found in both oases.

by Jaccard (1912), and it has been used rather widely by many investigators since that time. The values obtained by this procedure are found in Table V. The significance of coefficients of community given in Table V will be discussed in conjunction with the results of obtained from the treatment of data described in the following paragraphs.

Another comparison of oases was made using the IV's derived from the line intercepts and 1/40 acre quadrats. This comparison is basically a modification of Jaccard's coefficient of community. The specific form used here has long been used by a group of Polish ecologists (Curtis 1959, Whittaker 1967). It provides a coefficient of similarity or, as it is more commonly known, t e index of similarity. This can be used to compare stands where a series of quantitative measures are available for each stand, Indices of similarity can be calculated for any group of entities for which a number of different quantitative measures are available. The formula used here in t e calculation of index of similarity is 2w/a plus b, in which w represents the degree of coincidence between the two sets of measures. In practice w is the sum of lower values for each measure held in common between two stands. The other two terms in the formula, a and b, represent the sum of all measures in t e stands, where a stands for all the measures i one stand and b stands for all the measures in the other. The indices of similarity for all of the oases are presented in Table VI. This form of the index of similarity has been described by Bray and Curtis (1957), Curtis (1959), Kershaw (1964), and Whittaker

Table VI. Indices of Similarity

Oasis	OM	29I	49	CS	LP	MP	VS
	Oasis*						
Oasis of Mara	-						
Twentynine Palms Inn	33.2	-					
Fortynine Palms	16.0	34.9	-				
Cottonwood Spring	9.6	29.8	26.4	-			
Lost Palms	4.2	15.6	52.4	30.3	-		
Munsen Palms	3.4	38.4	48.5	17.2	48.4	-	
Victory Spring	3.4	21.8	34.2	23.9	20.4	48.1	-

* Abbreviations for oases used in this table are the same as those used in Table V.

(1967).

The values of the indices of similarity derived from the sampling of these oases was used to construct a two dimensional indirect ordination of the vegetation of the oases. In this technique of vegetational analysis the stands are arranged spatially in an effort to visually represent their positions relative to one another. The technique used in this study is similar to that described by Bray and Curtis (1957), Curtis (1959), Beals (1960), Kershaw (1964), and Whittaker (1967). In this method of analysis the indices of similarity for each stand are totaled. The stand with the lowest total is that stand which is most unlike all of the other stands. The oasis which proved to be most unlike the others was the Oasis of Mara. This stand was then used as an endpoint for the first axis of ordination. The oasis which was most dissimilar to the Oasis of Mara was Victory Spring. It was used for the second endpoint of the first axis. The length of the first axis was determined by the percent of dissimilarity between the two endpoint oases. All the distances used in the ordination are dissimilarity percentages or units. The other oases were placed on the first axis by means of the formula proposed by Beals (1960) in which the position of the intermediate oases is given by the expression, $x = (L^2 \text{ plus } D_1^2 \text{ minus } D_2^2) / 2L$. In this expression x represents the distance from the most dissimilar stand to the intermediate stand under consideration. The symbol L represents the length of the first axis, D_1 the distance from the intermediate oasis to the first end stand or oasis, and D_2 its distance or number of dissimilarity units to the second end stand. The preceding formula is based on the Pythagorean theorem. Beals subtracted his similarity values from a value of 85%. He considered any stands with similarities of 85% or greater to be essentially identical. Therefore the total maximum length which the first axis could approach using his method would be 85 units. For purposes of convenience I did not subtract the similarities from 85; instead I used a basis of 100%. After the intermediate stands were placed on the first axis a second axis was constructed to separate those stands which had been placed close together within 10% of the total length of L, though they were actually quite dissimilar. The distance of each of the oases from the first axis was approximated by use of the formula, $e = \sqrt{D_1^2 - x^2}$, in which x and D_1 represent the same entities as they did when placing the oases on the first axis, and e represents distance from the first axis. The stand with the highest e" value was chosen as the first endpoint of the second axis, and the stand most dissimilar to it was chosen as the second endpoint of the second axis. The two oases used as endpoints for the second axis were Lost Palms and Cottonwood Spring. The results of the two dimensional ordination are seen in Figure 2. It is possible to continue with a procedure similar to that just outlined until an ordination of several dimensions has been constructed. A multidimensional ordination was not practical in the case of these oases because of the very limited number of stands.

An examination of Tables V and VI and Fig. 2 reveals that there are some definite vegetational relationships and differences between oases. These values are all derived from the vegetation alone, yet they do reflect the influence of topography on the vegetational composition. Fortynine, Lost, and Munsen Palms form a natural grouping of three oases. This is evident even in a casual visit to these oases. The three oases show the highest coefficient of community and index of similarity values. In addition they have been closely placed together in Fig. 2. All three of these oases are found in rocky canyons. They all share certain species. *Salix exigua*, *Muhlenbergia rigens*, *Andropogon barbinodis*, *Brickellia arguta*, *Lotus rigidus* and *Baccharis sergiloides* are all important species in the vegetation of these oases. With the exception of *Zauschneria californica* and *Baccharis sergiloides*, which are found at Cottonwood Spring and *Lotus rigidus* which grows at Victory Spring, these species which are so important in these three oases are not found elsewhere. Because of their locations in rocky canyons there tends to be a sudden vegetational discontinuity between the vegetation of the oasis and that of the surrounding slopes. These oases appear to be less alkaline than the Oases of Mara and Twentynine Palms Inn. It will be noted that Fortynine Palms is more similar to Lost Palms than it is to Munsen Palms. This reflects the

FIGURE 2.

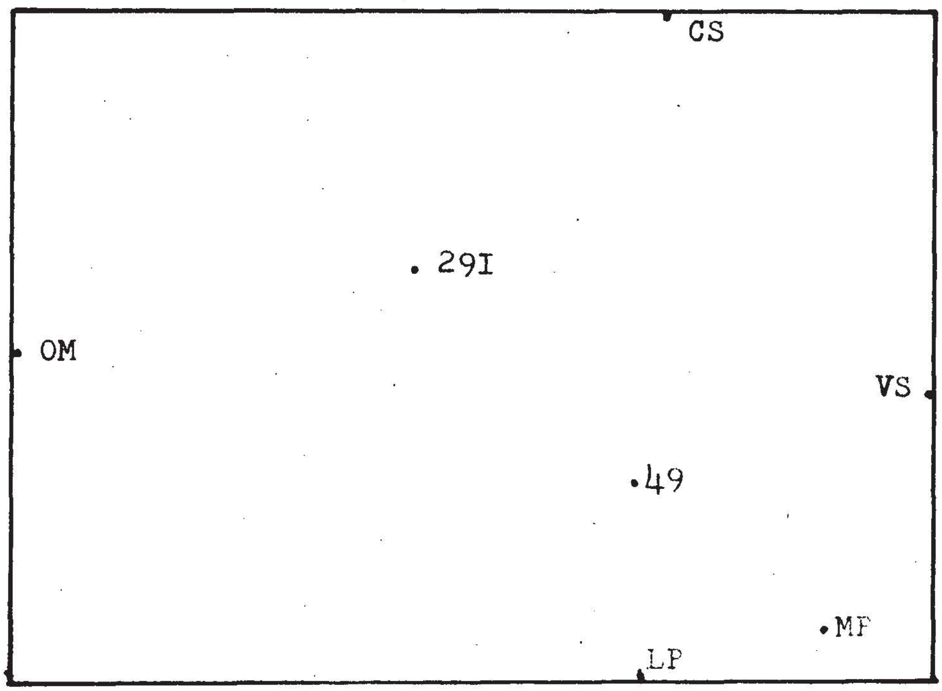

Fig. 2. Two dimensional indirect ordination of the oases of Joshua Tree National Monument. Key for the symbols used: Oasis of Mara (OM), Twentynine Palms Inn Oasis (29I), Fortynine Palms (49), Cottonwood Spring (CS), Lost Palms (LP), Munsen Palms (MP), and Victory Spring (VS). Note the grouping in the lower right-hand corner consisting of Fortynine Palms, Lost Palms, Munsen Palms, and more distantly, Victory Spring. Also note the relationship between the Oases of Mara and Twentynine Palms Inn.

amounts of water which are available to the vegetation of the oases, Fortynine Palms being the most hydric and Munsen Palms the most xeric of the three. There are several species which occur in two of the oases, but not in the third. *Epipactus gigantea*, *Machaerantha tortifolia*, and *Rhus trilobata*, are found only in Lost and at Fortynine Palms. *Salix lasiolepis* is also found in these two oases, and at the Oases of Mara and Twentynine Palms Inn. It is absent from Munsen Palms. Lost Palms and Munsen Palms each have significant numbers of individuals of *Juncus acutus* var. *sphaerocarpus*. In keeping with the greater degree of similarity between Fortynine Palms and Lost Palms than between Fortynine Palms and Munsen Palms, there are no species occuring in both Fortynine Palms and Munsen Palms which are absent in Lost Palms.

In Figure 2 it can be seen that Victory Spring is placed closer to Fortynine, Lost, and Munsen Palms than to any of the other three oases. It too is located in a rocky canyon. It is closest to Munsen Palms in terms of vegetation and in geographical distance. Victory Spring is much more xeric than the other three oases to which it is most closely related. MunsenPalms and Victory Spring share four species which are not found elsewhere in the oases (See Table III.).

Cottonwood Spring is clearly quite different from the other oases. It is the only artificially created oasis. Much of the vegetation there appears to be the same as that which is found in the washes and on the lower slopes of hills in the surrounding area. All except seven of the species present in the oasis are normally found in the surrounding area. Those species which are characteristic of oases are all wind disseminated except for California fan palm and honey mesquite. There are two introduced species, *Cynodon dactylon*, and *Phoenix dactylifera*. The *Phoenix* appears to be doing poorly, and it appears to have little or no chance to reproduce on this site. *Populus fremontii* will probably disappear from the oasis which bears its name in a few decades, or perhaps even less. This can be considered as a pioneer species in oases, and if present vegetational trends in the oasis continue, it can be stated that there will be no future sites which will be suitable for reproduction. This species, in common with most other members of the genus *Populus*, is known to be relatively short lived. This trait plus the lack of suitable reproductive sites spells the end of the species in that particular oasis. A fire or a flood could easily reverse this situation. The same state of affairs appears to prevail on the other oases with respect to this species.

The coefficient of community and the table of indices of similarity indicate that the Oasis of Mara is more closely related to the Oasis of Twentynine Palms Inn than it is to any of the other oases. This should not be surprising inasmuch as it is located in the same immediate area, and it could be considered to be an extension of the Oasis of Mara.

In this particular instance the coefficient of community can be considered to be a truer guide to the vegetational relationships between the Oasis of Twentynine Palms Inn. The man-caused disturbance and the recent fire have altered the vegetation at Twentynine Palms Inn. Because the importance values are composed of two relative parts, the elimination of fire intolerant species tends to increase the importance values of the California fan palm and of grasses. Those species such as honey mesquite which are fire intolerant are either absent or else their IV's are temporarily reduced to very low levels. Individual plants of those species whose importance have been reduced by fire or man's activities either escaped or have begun to grow again. As a result the coefficient of community provides a better measure of the floristic relationships than the weighted index of similarity.

Besides the effects of fire there are other differences which exists between the two oases. The ground water table appears to be much higher at Twentynine Palms Inn Oasis than on the Oasis of Mara. Recent soil disturbance appears to have been much more pronounced at Twentynine Palms Inn; in addition there are a number of structures within that oasis.

There are a number of species which are shared by both the Oases of Mara and Twentynine Palms Inn. All of the species occurring at the Twentynine Palms Inn Oasis also occur on the Oasis of Mara except for _Anemopsis californica_ and _Heliotropum curassavicum_ var. _oculatum_. _Atriplex polycarpa_, *Elymus triticoides*, *Haplopappus acradenius*, *Juncus balticus* and *Suaeda torreyana* are all species which do best in relatively deep, alluvial soils. All of the preceding species are locally important though they are found only in these two oases within the present study area. Honey mesquite, *Salix lasiolepis*, *Pluchea sericea*, California fan palm, *Atriplex canescens*, *Distichlis spicata*, and *Franseria dumosa* are species which occur in other oases in addition to these two.

There are several factors or ecological considerations which separate the Oases of Mara and Twentynine Palms Inn from the other oases within Joshua Tree National Monument. Both of these oases have deep, alluvial soils. The other oases are generally more rocky and they have thinner soils. In addition they are much more exposed to winds, in contrast to the relatively protected locations of the other five oases. The protection given by the mountains to the other five would certainly have to be considered relative protection. The Oases of Mara and Twentynine Palms Inn are more exposed to the winds that develop when low barometric pressures overlie the interior and high pressures exist over the eastern Pacific. When thermal lows develop over the Southwest, or after the passage of a Pacific low pressure system as it sweeps across the desert on its eastward journey to Arizona and New Mexico, wind velocities can attain high levels for a period of hours or days. The open position of these oases would conversely mean that they are less affected by the convectional winds that are so common around desert mountain ranges such as those in which the other fire oases are located.

The Oases of Mara and Twentynine Palms Inn are clearly more alkaline than the other oases. Only Cottonwood Spring, among the other five oases, had any appreacíable amount of salts on the surface of the ground. The remaining four oases are all either nonalkaline or only mildly so. It would be interesting to measure soil salinity and pH and to correlate plant distributions in the oases with such data. The Oases of Mara and Twentynine Palms Inn also lie at a lower elevation than any of the other oases within the Monument.

__Geographic Affinities of Component Species.__

An attempt was made to determine the geographic affinities of the component species of the oases. This was done by assigning all of the species into categories determined by their ranges and centers of distribution. This was done using floras and manuals by Munz (1959, 1969), Abrams (1940), Jepson (1925), and Mc Minn (1951). Even though the ranges of the component species all vary to greater or lesser degrees, each species was placed into one of 12 different groupings. Then the coverage and IV's for each of the groupings were calculated. Coverage and IV's by geographic group were computed for each oasis and totals were calculated on both equally weighted and on per unit sample bases. In addition the species list of each oasis was analyzed by group without regard to the coverage figures or IV's.

The various groupings used and their abbreviations are enumerated below. (1). Colorado Desert species (Col.). This group includes those species whose center of distribution lies in the Colorado Desert. Its most prominent species is the California fan palm. (2). Mohave-Colorado species (Moh-Col). These are species which occur widely in both the Colorado and the Mohave Deserts. The species included within this group were felt to be well within their ranges, and were often near the center of it. (3). Mohave Desert species (Moh). This was a small number of species primarily found on the Mohave Desert. (4). Mohave-Great Basin species (Moh-GB). These species are commonly found both in the Great Basin and on the Mohave Desert. (5). Mohave-Sonoran-Chihuahuan (Moh-Son-Chih). These species have wide distributions in the desert regions from the Mohave across the entire Sonoran Desert and are also found in the Chihuahuan Desert. They may or may not extend into the Great Basin area and extend beyond the desert into Texas or across the mountains to cismontane California. This is a small group numerically, but it is very important in terms of biomass. It includes Larrea divaricata and both species of Prosopis. (6). Transmontane, Great Basin and Great Plains group (Trans-GB-GP). This is a bispecific group. Only Atriplex canescens appears in the quantitative data. (7). Cismontane species (Cis). These are species which have their centers of distributions west of the mountain ridge that divides the coastal regions from the desert areas. (8). Cismontane-Transmontane species (Cis-Trans). These species commonly are found on both sides of the Sierra and southern Californian crests that divide the deserts from the coastal drainage. There is a great deal of variation in the ranges of some of these species. They may range into the Great Basin. They may also occur in different portions of cismontane California. Some, for example, occur in the San Joaquin Valley and not on the immediate coast. Others range from San Luis Obispo County south to Mexico and into the southern desert areas. Others extend into northern California. (9). Western North America (WNA). These species are widely distributed across the western part of the continent. (10). North American Species (NA). These species are found across the United States and southern Canada. (11). North America-Eurasian Species (NA-Eur). This consisted only of _Typha latifolia_ and _Juncus balticus_. (12). North and South American Species (NA-SA). This is another small group composed only of _Adantium capillus-veneris_ and _Bouteloua curtipendula_ which are distributed in both North and South America.

The results of the geographic analysis are shown in Tables VII and VIII. In terms of the oases as a whole, that species group whose distributions are centered in the Mohave and Colorado Deserts is by far the largest single geographic group, contributing an average of 38.5% per oasis to their floras.

Table VII. Geographic Affinities of Oasis Vegetation

OASIS	Geographic regions of distribution centers.	% of Flora	% Cover	IV's
OASIS OF MARA				
	Colorado Desert	3.7	6.2	6.8
	Mohave-Colorado	29.6	4.8	10.4
	Mohave-Sonoran-Chihuahuan	11.1	24.9	59.1
	Transmontane-Great Basin-Great Plains	3.7	-	-
	Cismontane	7.4	9.8	13.0
	Cismontane-Transmontane	22.2	24.8	93.5
	Western North America	7.4	4.7	4.6
	North American	11.1	10.0	12.5
	North America-Eurasia	3.7	0.2	0.2
TWENTYNINE PALMS INN				
	Colorado Desert	6.7	35.3	88.5
	Mohave-Colorado	20.0	-	-
	Mohave-Sonoran-Chihuahuan	6.7	4.5	7.4
	Transmontane-Great Basin-Great Plains	6.7	-	-
	Cismontane	6.7	11.3	[illegible].7
	Cismontane-Transmontane	33.3	4.9	33.4
	Western North America	6.7	67.5	46.6
	North America	6.7	11.4	15.3
	North America-Eurasia	6.7	1.0	0.7

Table VII. Geographic Affinities of Oasis Vegetation (cont.)

OASIS	Geographic regions of distribution centers.	% of Flora	% Cover	IV's
FORTYNINE PALMS				
	Colorado Desert	3.2	28.1	60.2
	Mohave-Colorado	29.0	9.6	53.0
	Mohave-Great Basin	6.5	0.3	1.0
	Mohave-Sonoran-Chihuahuan	3.2	1.2	3.0
	Transmontane-Great Basin-Great Plains	3.2	0.6	1.4
	Cismontane	16.1	13.1	43.6
	Cismontane-Transmontane	16.1	5.2	18.6
	Western North America	3.2	1.6	1.8
	North America	6.5	13.0	15.8
	North America-South America	6.5	1.2	1.6
	North America-Eurasia	3.2	-	-
	Introduced species	3.2	-	-
COTTONWOOD SPRING				
	Colorado Desert	13.6	20.8	40.1
	Mohave-Colorado	36.4	24.6	67.5
	Mohave-Sonoran-Chihuahuan	9.1	7.0	11.3
	Mohave-Great Basin	4.5	-	-
	Transmontane-Great Basin-Great Plains	4.5	19.2	54.3

Table VII. Geographic Affinities of Oasis Vegetation (cont.)

OASIS	Geographic regions of distribution centers.	% of Flora	% Cover	IV's
COTTONWOOD SPRING (cont.)				
	Cismontane	4.5	-	-
	Cismontane-Transmontane	18.2	3.4	26.7
	Introduced species	9.1	-	-
LOST PALMS				
	Colorado Desert	5.3	25.5	30.2
	Mohave-Colorado	47.3	20.6	68.5
	Mohave Desert	5.3	-	0.2
	Mohave-Great Basin	5.3	-	4.0
	Mohave-Sonoran-Chihuahuan	5.3	-	-
	Cismontane	15.8	31.6	91.2
	Cismontane-Transmontane	10.5	2.4	4.7
	Transmontane-Great Basin-Great Plains	2.6	-	-
	Western North America	2.6	-	0.6
MUNSEN PALMS				
	Colorado Desert	13.8	38.5	77.2
	Mohave-Colorado	51.7	14.6	63.9
	Mohave-Great Basin	3.4	6.6	25.2
	Cismontane	6.9	9.2	31.3
	Cismontane-Transmontane	13.7	0.4	2.4

Table VII. Geographic Affinities of Oasis Vegetation (cont.)

OASIS	Geographic regions of distribution centers.	% of Flora	% Cover	IV's
MUNSEN PALMS (cont.)				
	Mohave-Sonoran-Chihuahuan	6.9	-	-
	Western North America	3.4	-	-
VICTORY SPRING				
	Colorado Desert	16.7	38.5	77.2
	Mohave-Colorado	55.6	13.0	49.5
	Mohave-Great Basin	5.6	1.7	46.2
	Cismontane	5.6	-	1.9
	Cismontane-Transmontane	16.7	2.3	13.5

Table VIII. Geographic Affinities of the Total Flora of the Oases

Geographic Regions of Species Distribution Centers	Avg. % (per oasis) of the Flora	Avg. % Cover per Oasis	Avg. % Cover per Unit Sample	Avg. IV per Oasis	Avg. IV per Unit Sample
Colorado Desert	9.0	25.9	19.9	56.0	36.7
Mohave-Colorado	38.5	12.4	10.9	44.7	37.5
Mohave Desert	0.8	-	-	-	-
Mohave-Great Basin	3.6	1.2	.7	10.9	4.4
Mohave-Sonoran-Chihuahuan	6.0	5.4	10.9	11.5	25.1
Transmontane-Great Basin-Great Plains	3.0	2.8	2.0	8.0	5.5
Cismontane	9.0	10.7	12.9	27.1	30.8
Cismontane-Transmontane	18.7	6.2	11.6	27.6	45.6
Western North America	3.3	10.5	7.0	7.7	5.6
North America	3.9	4.9	6.6	6.2	8.3
North America-Eurasia	1.5	0.2	0.2	0.1	0.1
North and South America	0.9	0.2	0.2	0.2	0.2
Introduced species	1.8	-	-	-	-

This group also possesses high IV's. A difference will be noted between the average IV per oasis and IV per unit sample. The explanation for this lies in the fact that the group is better represented in the four southern oases than in Forty-nine Palms, Twentynine Palms Inn, and Mara Oases. Because of the larger number of samples in the three northernmost oases, the IV's of the Mohave-Colorado Group are lower on a per unit basis than in an average in which all oases are evenly weighted. Even though the Mohave-Colorado species aremore numerous than the species of any other group they do not dominate the flora of the oases. They are exceeded in both coverage and importance values in all oases except Cottonwood Spring where much of the vegetation which was there prior to its formation still exists in a relatively unaltered state. Most of the Mohave-Colorado species tend to be small, though they may be quite numerous. Baccharis sergiloides and Salix exigua are the two most important species in this group. Both occur in large numbers. Brickellia arguta, Simmondsia chinensis, Lotus rigidus, Sphaeralcea ambigua, and Acacia greggii are other prevalent species which were placed in this group. All of the above species tend to be small or intermediate in size. Acacia greggii and Simmondsia chinensis can attain fairly large sizes, but most of the individuals encountered in this study did not.

The second largest group of plants in the oases is the Cismontane-Transmontane group. This group was found to have the second highest number of species in the flora of the oases, and in addition it yielded the highest figures of average IV per unit sample. This group is most strongly represented in the Oases of Mara and Twentynine Palms Inn, two of the important species in these oases; _Populus fremontii_ and _Pluchea sericea_, are often wind distributed. _Populus fremontii_ occurs also at Fortynine Palms and Cottonwood Spring. Another Cismontane-Transmontane species which is wind distributed is _Epipactus gigantea_. Other Cismontane-Transmontane species are not wind distributed. Some of them are probably bird distributed. I would like to know how the fruits and seeds of _Juncus acutus_ var. _sphaerocarpus_ and _Suaeda torreyana_ are disseminated. There are many other species whose mode of dissemination is not clear. It seems unlikely that those oases which are most exposed to the westerly prevailing winds would have the highest number of Cismontane-Transmontane species by pure chance.

The group of species which are centered in the Colorado Desert is small in numbers of species, but the group is quite important in the oases as evidenced by high coverage and IV's. Without the values for the California fan palm the values for this group would be very low. This is not surprising because this species characterizes the oases. This group is most strongly represented in the southernmost oases which are contiguous to the main area of the Colorado Desert. The northernmost oases contained only one Colorado Desert species, the California fan palm itself.

There is a small, but numerically important Cismontane group which occurs in all oases. Its most important species is *Muhlenbergia rigens*. *Eriogonum fasciculatum* var. *flavoviride* was included in this group even though the variety itself is generally transmontane. These two species are probably bird or perhaps rodent distributed. *Salix lasiolepis*, *Zauschneria californica* sp. *latifolia*, and probably *Equisetum funstoni* are wind distributed. This group is most strongly represented in Fortynine and Lost Palms.

The Mohave-Sonoran-Chihuahuan species contribute more to coverage figures and IV's than its limited numbers of species might lead one to expect. Its most important species is honey mesquite. *Prosopis pubescens*, and *Larrea divaricata* are also in the same group. There are some significant differences in the ranges of these species. For example *Prosopis pubescens* is found as far to the northwest as canyons west of Coalinga, in Fresno Co., California. Honey mesquite ranges to the upper part of the San Joaquin Valley and it is also found at various points in cismontane southern California. *Larrea* too, is found at several places in cismontane southern California (Munz 1959). The populations of these species in cismontane California are rather insignificant when compared to the populations of transmontane areas, and for this reason they were disregarded when the geographic groupings were set up. These species also show great differences in their eastern and southern limits. Larrea divaricata occurs in Argentina where a large and very disjunct population is found. Nevertheless it was found to be most convenient to group them into the Mohave-Sonoran-Chihuahuan group. This was done on the basis of their behavior in the United States and northwestern Mexico. This aggregation of species reaches its maximum importance in the Oasis of Mara where the honey mesquite has become the main dominant species in much of the oasis and threatens to engulf much of the rest.

Several species were included in the Mohave-Great Basin group. The most prominent species, Gutierrezia microcephala, is commonly found in the rocky slopes in much of the area. This species is small and often quite numerous. Two other species in this group are Coleogyne ramosissima and Ephedra nevadensis. Both of these species are commonly found on dry slopes and in canyons of the Monument.

The species of the remaining groupings are all species which are widely distributed. With the exception of Atriplex canescens which ranges as far as the Great Plains and Apocynum cannabium var. glabberimum which is widely distributed in North America, all of the species within these groups are either spore distributed or they are monocotyledons (mainly grasses). Several of these species have distributions which include more than one continent. Juncus balticus occurs in Asia and Europe in addition to North America. Another widespread species which was included in the North American group is *Phragmites communis* var. *berlandieri*. The species as a whole is said to be the most widely distributed vascular plant in the world (Polunin 1960). Another widespread plant which occurs in these oases is *Distichlis spicata*. The populations from the Colorado and Mohave Deserts have been segregated out as *Distichlis spicata* var. *divaricata* (Beetle 1943). Other authors have raised varieties to the rank of species (Hitchcock 1950, Scoggan 1957, Stevens 1963). I have seen specimens from different parts of the country, and I am inclined to put them into the same species. However, I should state that I am a taxonomic conservative. For this reason *Distichlis* has been included in the North American group in this study.

The Oases of Mara and Twentynine Palms Inn have the highest complement of these very widespread species. This can be attributed to the alkaline conditions and to exposed locations. Many species which are commonly found on alkaline sites are species which have wide distributions with scattered populations. I would suggest that these species which are restricted to alkaline sites either through competition with other species or through physiological factors require wide distributions in order to occupy enough physical area so that sufficient numbers and populations will exist to insure their survival. Those species which fail to adapt to a wide variety of climatic and other environmental conditions, and which are restricted to alkaline sites through competition and/or for physiological reasons, are doomed to extinction if environmental changes occur within a very limited area of distribution.

In conclusion it can be said that the largest number of the species found in the oases have their centers of distributions in the desert regions of California and adjacent areas of nearby states. Another sizable group of species is centered in both cismontane and transmontane areas. A number of species reach the area of these oases from coastal regions, and for several the oases mark some of the most inland extensions of their ranges. The group of species centered in the Colorado Desert is small in terms of species numbers, but it ranks high in coverage and IV's. The same is true of the few widespread species which extend through the desert areas of the southwest all the way into Texas and Mexico. Those species whose distributions cover vast areas of the continent or world are important only in the three northernmost oases. Vegetational relationships of the oases are thus primarily with the area in which they occur, to a lesser extent with the southern California coast, and also with the desert regions of the south and east. Vegetational relationships with the north are confined to a few species from the Mohave and Great Basin, and more importantly with those species which have very wide distributions in North America.

A Comparison Between The Oases Of The San Andreas Fault And Those Of The Joshua Tree National Monument

One of the main objectives of the present study has been to compare the oases of Joshua Tree National Monument with those of the Coachella Valley. A comparison of the prevalent species in these oases reveals some significant differences. The number of prevalent species in the oases of the Monument is more than twice that of the oases along the Fault. Since the number of prevalent species is determined by the mean number of species for all the stands considered, it is evident that alpha species diversities are much higher in the oases of the Monument. The number of prevalent species in the oases of the National Monument and the San Andreas Fault are 26 and 11, respectively. Further evidence of difference is shown by the limited number of prevalent species which are shared by both groups of oases. Out of a total of 33 prevalent species only four occur in both groups. Out of the 11 prevalent species in the San Andreas Fault oases nine do occur somewhere in the oases of the Monument, most often at the Oasis of Mara. Conversely, 14 of the 26 prevalent species of the Monument oases occur in some oases along the San Andreas Fault. Species which were found to be prevalents in both groups of oases are the California fan palm, honey mesquite, *Pluchea sericea*, and *Distichlis spicata*. Prevalent species from the San Andreas Fault which are absent from the Joshua Tree National Monument Oases are *Scirpus olneyi*

Table IX. Prevalent Species from Both San Andreas Fault and Joshua Tree National Monument Oases by Per Cent Dominance

Species	Avg. % Dominance per San Andreas Fault Oases	Avg. % Dominance per Monument Oases	Avg. % Dominance per Unit Sample in Monument Oases
Washingtonia filifera	21.0	24.3	19.8
*Haplopappus acradenius**	3.8	0.5	1.5
Pluchea sericea	2.9	0.9	1.6
Sporobolus airoides	2.8	P	P
*Suaeda torreyana**	1.7	2.4	5.1
Prosopis juliflora	4.1	5.2	10.4
*Juncus acutus**	2.6	2.0	2.4
Atriplex hymenelytra	1.1	-	-
Scirpus olneyi	3.4	-	-
*Atriplex polycarpa**	1.5	0.5	1.3
Distichlis spicata	4.6	2.6	3.5
Acacia greggii	P	0.8	0.5
Simmondsia chinensis	-	P	P
Phorodendron californicum	P	0.1	0.1
Baccharis sergiloides	-	5.4	3.4
Gutierrezia microcephala	-	0.5	0.2
Salix lasiolepis	-	4.6	5.2
Isomeris arborea	P	0.5	0.3
Prunus fasciculata	-	0.9	0.6

Table IX. Prevalent Species from Both San Andreas Fault and Joshua Tree National Monument Oases by Per Cent Dominance (cont.)

Species	Avg. % Dominance per San Andreas Fault Oases	Avg. % Dominance per Monument Oases	Avg. % Dominance per Unit Sample in Monument Oases
Zauschneria californica	P@	0.5	0.6
Coleogyne ramosissima	-	0.7	0.4
Lotus rigidus	-	0.1	0.1
Sphaeralcea ambigua	P@	0.3	0.1
Eriogonum fasciculatum	P@	P	P
Muhlenbergia rigens	-	6.4	6.9
Salix exigua	P@	2.0	2.1
Atriplex canescens	P@	2.8	2.0
Populus fremontii	P@	1.2	2.6
Yucca whippleyi	P@	P	P
Viguiera deltoidea	-	0.1	0.1
Brickellia arguta	-	P	P
Lycium andersonii	-	P	P
*Elymus triticoides**	-	2.4	5.1

* denotes species which are not prevalent species in the Monument oases, but the data was included for the sake of interest and comparison

P means the species is present but that it did not appear in dominance figures

P@ signifies that these species do occur somewhere in one or more oases in the area of the San Andreas Fault and *Atriplex hymenelytra*. *Gutierrezia microcephala*, *Brickellia arguta*, *Salix lasiolepis*, *Simmondsia chinensis*, *Baccharis sergiloides*, *Muhlenbergia rigens*, *Prunus fasciculata*, *Lotus rigidus*, *Coleogyne ramosissima*, *Andropogon barbinodis*, and *Viguiera deltoidea* var. *parishii* are prevalents from Monument oases which do not occur in any of the San Andreas Fault oases. A list of the prevalent species of both oasis groups is found in Table IX. In addition, coverage figures are present for both groups. Both average percent cover per oasis and average percent cover per unit sample are presented for the oases of the Monument, and average percent cover per oasis alone for the oases of the San Andreas Fault.

Coverage values are similar in both groups of oases for three species which are shared as prevalent species. This is true for California fan palm, honey mesquite, and *Distichlis spicata*. However, *Pluchea sericea* has much lower coverage or dominance in the oases of the Monument.

The foregoing two paragraphs demonstrate that there is a significant difference between the dominant vegetation of the oases of Joshua Tree National Monument and those of the San Andreas Fault. However, the difference in prevalent species is only one facet of the differences which exist between these two groups of oases.

The oases were analyzed in terms of family importance. The earlier study made of the San Andreas Fault oases used IV's which were based on absolute instead of relative dominance, relative density and the number of individual plants encountered in line intercepts (Vogl and Mc Hargue 1966). This procedure yielded an IV total of 300 instead of the 200 total used in the present study. For this reason IV's from the earlier study and the present study are not directly comparable. For that reason I have chosen to use absolute dominance as a measure, because comparable values are readily available from both studies. A comparison of the two sets of oases is found in Table X.

Some plant families appear to have importances of the same magnitude in both oasis groupings. This is true of the families Palmae, Leguminosae, Compositae, and Chenopodiaceae. A number of the same species were present in bot groups of oases in about the same numbers, and hence their value are similar. Other families do not occur equally in the oases. This is true of the remainder of the families listed in Table X. The families Cyperaceae and Tamaricaceae are more important in t e oases of the San Andreas Fault, and they appear to be totally absent from the oases of Joshua Tree National Monument. The only important Cyperaceae species is Scirpus olneyi which is the dominant species around mildly alkaline springs and on very wet ground. Tamarix pentandra of the Tamaricaceae has become quite widespread in the Imperial, Coachella, and Colorado River Valleys and many other areas of the southwest. It has attained a position as a dominant species in a number of the palm oases in the Coachella Valley.

Table X. Major Plant Families in Both the San Andreas Fault and Joshua Tree National Monument Oases by Per Cent Dominance

Families	Avg. % Dominance per San Andreas Fault Oasis	Avg. % Dominance per Monument Oasis	Avg. % Dominance per Unit Sample of Monument Oases
Palmae	21.8	25.6	19.8
Gramineae	8.0	20.8	18.7
Leguminosae	6.7	6.2	11.7
Compositae	8.6	6.4	7.7
Salicaceae	1.5	6.9	9.9
Juncaceae	3.3	0.4	0.5
Chenopodiaceae	6.8	5.7	8.4
Cyperaceae	3.6	-	-
Equisetaceae	-	1.9	1.9
Tamaricaceae	0.8	-	-
Capparidaceae	-	0.5	0.4
Roasaceae	-	5.8	2.3
Malvaceae	-	0.3	1.5

It is fortunate that a similar position has not been attained in the oases of the National Monument. The same species of Juncus appear in the floras of both groups of oases, but Juncus acutus var. sphaerocarpus is much more important in the Fault oases.

The families Gramineae, Salicaceae, Equisetaceae, Capparidaceae, Rosaceae and Malvaceae are considerably more important in the Monument than in the oases of the Coachella Valley. The greater importance of the latter three families reflects the greater species diversities of their surrounding areas. It is clear that the Eagle Mountains are rich in species when compared to the depauperate flora which occupies the lower elevations of the Coachella Valley. There is a definite trend toward a reduction in oasis species numbers with decreasing elevation as one traverses the San Andreas Fault. An average 1000 m^2 area on a bajada in the vicinity of the lower elevation oases near Indio usually contains five or six perennial species. The same area in the canyons of the Eagle Mountains will yield three or four times that number of species, and in places even more.

The family Gramineae is more important in the Monument oases than those of the San Andreas Fault largely because of the presence of Muhlenbergia rigens in Lost Palms, Munsen Palms, and Fortynine Palms. This species is entirely lacking in the oases of the San Andreas Fault. Another species of the family Salicaceae, Salix exigua, is found in the same three oases. Unlike *Muhlenbergia* it is found in the San Andreas Fault oases. In the latter group of oases, even though it isn't usually a major species, it is still the most important member of the family. In the Monument oases *Salix lasiolepis* and *Populus fremontii* also contribute substantially to the importance of that family. The Equistaceae is important because of the large population of *Equisetum hymale* var. *robustum* at Fortynine Palms.

Another means by which these two groups of oases were compared to one another was by use of the coefficient of community. All the oases of the Monument were compared to nine selected oases from the San Andreas Fault. Each of the oases in these two groups were compared to one another and then the two groups were compared. This was done in order to determine the degree of internal relationships so that the relationships between the two groups of oases would be more meaningful. The community coefficients between the separate oases of the San Andreas Fault oases are seen in Table XI.

The oases of the San Andreas Fault can be divided into two basic types, wash and seep oases. Wash oases are found on the bottoms of canyons where they are subject to floods which will scour the wash bottoms and remove and redeposit gravel, rocks and soil. The Seep oases occur on hillsides where the abrasive action of water is absent and the soil is stable and is often quite fine in particle size. Thousand Palms, Simone Palms and Pushawalla are all wash oases, and

Table XI. Coefficient of Community for the Oases of the San Andreas Fault

Oasis	Oasis[a]								
	WP	1000	SP	Ind.	HP	HoP	Push	No	Mac
Willis Palms	-								
Thousand Palms	27.5	-							
Simone's	44.0	60.0	-						
Indian Palms	47.4	28.6	36.0	-					
Hidden Palms	36.0	37.5	48.1	23.1	-				
Horseshoe Palms	37.5	31.7	25.8	40.9	27.5	-			
Pushawalla	32.2	63.2	74.1	30.0	36.4	33.3	-		
Nomad Palms	28.6	10.5	17.4	46.2	25.0	33.3	37.5	-	
Macomber Palms	32.2	44.2	34.3	39.3	36.4	37.5	26.8	23.1	-

a. The abbreviations and their meanings are as follows: (WP) Willis Palms, (1000) Thousand Palms Oasis, (SP) Simone's Oasis, (Ind.) Indian Palms, (HP) Hidden Palms, (HoP) Horseshoe Palms, (Push) Pushawalla Canyon, (No) Nomad Palms, and (Mac) Macomber Palms.

Table XII. Community Coefficients Between the Oases of Joshua Tree National Monument and those of the San Andreas Fault.

Oasis	Oasis[a]								
	WP	1000	SP	Ind	HP	HoP	Push	No	Mac
Oasis of Mara	31.2	31.2	45.5	25.0	31.4	25.0	32.5	17.9	23.0
Twentynine Palms Inn	30.4	22.5	33.3	27.3	25.9	26.9	20.5	23.5	20.5
Fortynine Palms	9.5	14.9	20.9	7.3	11.1	11.4	11.8	8.8	11.8
Cottonwood Spring	8.8	9.4	16.2	6.1	10.8	11.1	9.1	3.7	6.7
Lost Palms	8.2	12.1	15.1	6.2	7.5	9.8	10.3	7.3	10.3
Munsen Palms	9.7	14.0	13.6	10.5	11.6	11.9	12.2	9.3	17.0
Victory Spring	3.1	4.8	8.3	11.3	8.8	2.9	3.8	4.3	10.5

a. The abbreviations in this table are the same as those of Table XI.

it can be seen in Table XI that they are more closely related to each other than they are to the other oases. An examination of Table XI and a comparison of coefficients of community of these oases with those of the Monument Oases as shown in Table V reveals that there is more internal consistency between the oases of the San Andreas Fault than between the oases of the National Monument, even though the community coefficients are quite low. This is not too surprising because the San Andreas Fault oases are located in relatively close proximity while the oases of the other group are more widely scattered.

The oases of the Fault and the National Monument are compared to each other in Table XII. When the figures of this table are examined a rather interesting pattern is observed. The oases of the National Monument which most resemble the oases of the San Andreas Fault are the Oases of Mara and Twentynine Palms Inn. The coefficients of community produced by a comparison of these two oases with Fault oases yield values that approach the degree of internal consistency of the San Andreas Fault oases considered alone. The Oases of Mara and Twentynine Palms Inn together have populations of all of the prevalent species of the Fault oases except for _Juncus acutus_ var. _sphaerocarpus_, _Scirpus olneyi_, and _Atriplex hymenelytra_. Several of the "rare" species discussed earlier grow there in large numbers, even though they are absent in the other oases of the National Monument.

Another, more subtle pattern emerges from these figures as well. The Oases of Mara and Twentynine Palms, the oases most exposed to the westerly winds that blow into the desert from the coast, are most similar to those oases on the San Andreas Fault which are similarly exposed. Pushawalla Canyon offers an exception to this generalization. Willis Palms, Simone Palms, and Thousand Palms Oasis are the most exposed fault oases of those considered in this section. Species which occur in all of these exposed oases are _Pluchea sericea_, honey mesquite, _Distichlis spicata_, California fan palm, _Suaeda torreyana_, and _Atriplex polycarpa_. _Prosopis pubescens_, _Populus fremontii_, _Atriplex lentiformis_ and _Phragmites communis_ all occur at Thousand Palms, Simone Palms, and the Oasis of Mara. Species which occur at Willis Palms and at the Oasis of Mara include _Apocynum cannabium_ var. _glaberrimum_, _Sporobolus airoides_, and _Juncus balticus_ or perhaps _J. mexicana_, a taxon which is doubtfully distinct from _J. balticus_ (Munz 1959, Abrams 1940).

It should be remembered that even though the oases discussed in the preceding two paragraphs are more similar to each other than they are to other oases in opposite groups, the coefficients are still rather low. These communities are more different than they are similar. All of the oases in Joshua Tree National Monument which are located in rocky canyons show coefficients of community when compared to the San Andreas Fault oases which are very low. Victory Spring, for example, has only the California fan palm in common with

Willis Palms, Horseshoe Palms, Pushawalla Palms, and Nomad Palms. Only the Oases of Mara and Twentynine Palms Inn share any appreciable number of species with the oases of the San Andreas Fault, and even there community coefficients are below 50%.

Oases and Fire

Fire is clearly a major factor affecting the vegetational composition of California fan palm oases (Vogl and Mc Hargue 1966). Palm oases are peculiarly suited to fire by virtue of the heavy thatch of dead fronds on the trunks of the trees. The author can attest to the extreme inflammability of these fronds from personal experience. When lighted with a match or thrown on a camp fire they almost explode into flame. In contrast to the leaves of most plant species, palm fronds are easily ignited by using a hand lens to focus the sun's rays on them. This is presumably due to the heavy layer of surface wax which remains on dead fronds. In oases which have been unburned for long periods of time massive amounts of dead or senescent plant materials accumulate. These plant materials add enormous amounts of potential fuel to an oasis.

Nearly all of the oases characterized by the presence of California fan palm are known to have burned at some time in the past. Old photographs of the Oasis of Mara (see photographs at back) and the oases of the San Andreas Fault show burned palms (Jepson 1910, 1922, Mac Dougal 1908, Van Lahr 1969). Fire records for the oases within Joshua Tree National Monument are quite incomplete, but all of the natural oases show the effects of fire to a greater or lesser degree. The Oasis of Mara is known to have burned many years ago. I was unable to ascertain the last date of burning. The palm trees at the Twentynine Palms Inn Oasis burned just a few years ago, and the effects of the fire are quite evident. Forty Nine Palms Oasis burned on June 23, 1948, according to Monument records. At that time 44 large palms burned, six were partially burned, and three remained untouched. Lost Palms is also known to have burned in the late 1940's. Patchen (1964) has a photograph showing an old burn. Munsen Palms shows definite signs of fire having swept through the oasis. I would estimate that the oasis burned 30 to 40 years ago.

The presence of fire in oases is not a new influence which was unknown prior to the advent of European man. Burning of the palms by Indians removed the highly flammable thatch of dead fronds which they believed harbored evil spirits (Henderson 1961, James 1907). This process is also said by these two authors to have been carried out for the purpose of obtaining increased seed yields following fire. I can attest to the dramatically increased yield of palm seeds as a result of fire having observed this several times. Another personal comment might be in order here as well. After having camped out in a number of remote, isolated palm oases as a teenager I find the Indian superstition regarding the palm thatch to at least be understandable. The Indian custom of palm burning provides an example of a religious custom which has a beneficial, practical value to a primitive people.

Oasis fires can begin without the action of man. Lightning has been known to start fires in oases (Gardner 1961, Henderson 1961). Gardner (1961) found freshly burned oases (in Baja

California) in remote and inaccessible canyons which the few local residents said had not been visited by man in at least twenty years. He suggested that dead fronds rubbing against each other during periods of hot, dry winds might generate enough static electricity to produce sparks and kindle fires. Spontaneous combustion has also been suggested as a possible source of fire in oases with large amounts of wet, hydric vegetation (Vogl and Mc Hargue 1966).

Fire seldom kills or seriously damages individual,mature fan palms. They are clearly adapted to withstand repeated burning. Numerous fires in oases of the San Andreas Fault have shown that quick, wind-driven fires do relatively less damage than fires which occur during periods of little or no air movement (Vogl and Mc Hargue 1966). The apical meristem of palms is so deeply placed in the interior of the plant that fire can seldom heat it sufficiently to cause death. A fire in the spring of 1967 in Thousand Palms Canyon killed several trees by burning almost through the base of the trunk, rather than killing the terminal bud. This was shown when those trees began to put forth new fronds before the death of the trees actually took place.

The presence or absence of recent or recurring fires on different growing sites may be responsible for some of the confusion surrounding the taxonomy of the representatives of the genus Washingtonia in the United States. Fires tend to burn the outermost portion of the trunk. Repeated fires will therefore reduce the number of functioning vascular bundles and consequently the trunk diameter. This in turn will alter the size, number, and perhaps other characteristics of the leaves and crown. Since relative trunk diameter and the size and shape of leaves and crown have been used as diagnostic taxonomic characteristics (Parish 1907, 1909, Bailey 1936, Henderson 1961) it seems likely that fire's effects on palm morphology may have contributed to some of the confusion that has surrounded the taxonomic status of the genus *Washingtonia*.

Fire as a biotic factor is often quite beneficial to a population of California fan palms. The elimination of fire intolerant understory and overstory species benefits the palms by reducing competition for growing space, light, and perhaps water and mineral nutrients. Palm seedlings are seldom found in deep shade, though they can tolerate a certain reduction in the intensity of sunlight. Those oases along the San Andreas Fault which have the highest rates of palm reproduction are those oases in which there are relatively open areas occupied by grasses or where there are significant areas of moist bareground. Another way in which fire can be beneficial to palms is the release of young palms from supression of arborescent woody species. Oasis fires burn off fire intolerant species which can and do suppress young palms by means of shading. The aftermath of an oasis fire is a young palm which is exposed to full sunlight, and a consequent increase in its growth rate. This is a particularly pronounced phenomenon in cases where honey mesquites have suppressed young palms.

Fire exerts a differential effect on the various other species of plants which occur in the oases. These effects range from beneficial to deleterious. It should be stated however that though a fire may be beneficial to a population of a species it may not be beneficial to individuals of that species growing on the site at the time a fire occurs. Those understory species which appear to increase soon after an oasis fire either possess underground or protected buds, or they are able to respond favorably to fire as a result of favorable, open sites which are fire created.

The family which appears to be most benefited by fire (except perhaps the family Palmae itself) is Gramineae. In the oases of the Coachella Valley Distichlis spicata and Sporobolus airoides are both known to increase in importance after fire (Vogl and Mc Hargue 1966). Sporobolus is represented within Joshua Tree National Monument by a relatively few individuals in the Oasis of Mara, but Distichlis is a constituent of the vegetation of the oasis of Mara, Twentynine Palms Inn Oasis, and Fortynine Palms Oasis. Distichlis importance values show that the species is most common in Twentynine Palms Inn Oasis, the oasis which has been burned most recently. In the Oasis of Mara, Distichlis appears to be in decline due to the growth of woody species and its consequent shading out. Distichlis is a very minor component of the vegetation at Fortynine Palms Oasis, probably due to gradually increasing numbers of woody species and the fact that it is less saline than the other oases where the species occur.

The most important grass in the oases of the Monument is Muhlenbergia rigens. This grass is a tufted perennial which is very prevalent in Lost Palms, Munsen Palms, and in Forty-nine Palms, where fire effects are quite evident. The tufts appear to be quite inflammable, though I did manage to resist the impulse to put this observation to test. The large amounts of this grass, particularly in Lost and Munsen Oases, have probably grown since the last fires in these oases. This species occupies the same ecological position in these three oases that is occupied by Sporobolus airoides in the oases of the Coachella Valley. Sporobolus is rejuvenated by fire in those oases, and I believe that an experimental burning of a few clumps of Muhlenbergia would show precisely the same effects in the oases of the Monument. The apical meristems of this species appear to be sufficiently well insulated so that the plants would soon regenerate after a fire.

Other species which resist fire damage are those species possessing underground rhisomes or roots which are capable of producing new shoots after a fire. Pluchea sericea and Typha latifolia are two species which have this ability. Both Pluchea and the various Typha species resprout very quickly after fire. These species are adapted to fire so well that they can withstand repeated burnings by flamethrowers to which they are subjected by the Imperial Power and Irrigation District in a continual effort to keep irrigation ditches and canals of the Imperial Valley open (Vogl and Mc Hargue 1966).

Another species which seems well adapted to fire is Juncus balticus. It seems to require moist, open sites and it spreads by means of subsurface rhizomes. Its highest importance value is at Twentynine Palms Inn Oasis, where the most recent of the oasis fires occurred.

Two additional species appear to recover from fire somewhat more slowly that the preceding, though they do derive some benefits from fire. Salix exigua and Baccharis sergiloides are both quite important species in the oases of Lost Palms, Fortynine Palms, and Munsen Palms. Successful establishment of seedlings seems to require open, moist sites with mineral soil. Both species probably recover from fire more slowly than the grasses or the palms.

Several species are known to be quite intolerant of fire. Prosopis juliflora var. torreyana and Prosopis pubescens both are quite intolerant of oasis fires. It is no accident that Prosopis composes a relatively insignificant portion of the vegetation of Twentynine Palms Inn, Lost Palms, Munsen Palms, and Fortynine Palms Oases. In contrast, the Oasis of Mara which has been unburned for decades is overgrown with honey mesquite. A fire in the Oasis of Mara would probably kill a significant portion of the honey mesquites within the oasis. A side effect of such a burn would be a reduction in the number of clumps of Phorodendron californicum (mesquite mistletoe). The infection of the mesquites is density dependent, and any reduction in the numbers of honey mesquites would reduce the chance of the mesquite mistletoe seeds reaching a favorable site.

Another species which has been shown to recover slowly from fire is Haplopappus acradenius. Other species found in the oases which are quite intolerant of fire are Populus fremontii, Salix lasiolepa, Atriplex lentiformis, Suaeda Torreyana, and most of the plants which grow in the surrounding desert areas where no high, permanent water table exists. These species are usually killed by the passage of a fire through an oasis, but fire often provides new sites for seedling plants that will replace those individuals which are lost.

Successional patterns which can be observed after fires tend to be rather truncated when compared to the classic plant ecological description of succession in the eastern deciduous forest. Nevertheless patterns do exist. They show a strong resemblance to patterns existing in other fire adapted vegetation types found both here in California and in other parts of the world. Regeneration of vegetation comes from those species in which the individual plants are adapted to withstand fire, and those plants which are enabled to reproduce as a result of fire caused environmental changes. After an oasis fire the palms and the grasses may begin to resprout within a few days. After the fire in Thousand Palms Canyon in 1967, Pragmites communis and Distichlis spicata, began to resprout within a week. Within a month the palms were producing new fronds and the Pluchea sericea was resprouting also. Two months after the fire the measurable cover of Phragmites and Distichlis was far higher than it had been before the fire. In some parts of the canyon pre and post fire coverage figures differed by magnitudes of more than ten. Since that time shrubs and taller herbs have begun to displace some of the *Distichlis*. The same site supported many individuals of *Prosopis juliflora* and *P. pubescens* as well as a sizable population of *Tamarix pentandra*. The *Prosopis* species have resprouted very weakly, and it will be many years before these two species regain the same degree of importance which they had attained before the fire. (In contrast the *Tamarix* has resprouted vigorously. It is fortunate that this species has not become naturalized in the oases of Joshua Tree National Monument.)

The regrowth of the palms and grasses (and some other rhizomatous and root sprouting species) is followed by the establishment of new populations of those species killed by fire. This occurs at varying rates depending on the species involved. It obviously requires more time to re-establish a population of trees than small shrubs. In common withmost fire-adapted vegetation types this process proceeds much faster than secondary succession in non-fire adapted vegetation types. The oases of the San Andreas Fault appear to recover quite well within a year if an adequate supply of ground water is present. This does not mean that the oasis will attain a pre-fire vegetational composition, but it will appear green with vegetation, and the main evidence of fire's having burned the oasis will be seen in the blackened trunks of the palms and perhaps a few burned pieces of wood scattered about. The rates of vegetative regeneration in the oases of the National Monument appear to be somewhat slower than in the oases near Indio. This may be due in part to slower rates of growth caused by lower winter temperatures.

Patterns of succession are not identical in all of the oases considered in the present study. They are quite different. The oases which most closely resemble the oases of the Coachella Valley in successional patterns are the Oasis of Mara and the Twentynine Palms Inn Oasis. None of the major oases along the San Andreas Fault have remained unburned as long as the Oasis of Mara.

Fires in Fortynine Palms, Munsen Palms and Lost Palms would result in a different sequence of events. The leading fire resistant species there is Muhlenbergia rigens. This species is the most important species at Lost Palms, and it ranks second only to the California fan palm itself in the other two oases. At the present time many tussocks of this species would be established after the Muhlenbergia resprouts following a fire. The sequence differs between oases due to their high species variability.

The available information indicates that fire should be considered a natural biotic factor in California fan palm oases. They have most likely burned periodically throughout the history of this vegetational community. It can be safely stated that prolonged periods without the action of fire will lead to the diminuation of the importance of some species or even to their extinction in the oases. Given a sufficiently long interval of time this applies even to the palms themselves.

Palm Reproduction

One of the purposes of the present study has been to determine the rate at which the palms are reproducing and the outlook for the future of the California fan palm within the Monument.

One of the most valuable kinds of information to have would be the ages of the individual palms. Unfortunately it is not possible to age the palms because they are monocotyledons and thus have no annual rings. Maximum ages attained by the California fan palms have been the subject of some wild exaggerations in popular literature. Statements have been made that individual trees may reach ages of 2500 years. Such inflated claims of age may make for interesting reading and add a romantic aura to a grove of palms, but it is simply contrary to fact. Henderson (1951) believes that individual palms of 150 years of age are common, and that the maximum age of palms is something over 200 years. Attempts were made to estimate the age of palms in the cases of the San Andreas Fault by means of measuring the length of thatch produced since a fire of known date and comparing thatch length to the total trunk length (Vogl and Mc Hargue 1966). This method suffers from the difficulty that palms do not have even growth rates throughout the duration of their lives. This method yielded a maximum life span of about 200 years, but most palms appear to succumb before reaching an age of 150 years.

A census of palms was made in each of the oases in Joshua Tree National Monument. All the palms of each oasis were divided into three size classes. Size class I consisted of all seedling palms. Size class II was composed of those palms which were larger than seedlings, but which had not yet attained the full number of vascular bundles in their trunks and consequently had not yet reached the adult trunk diameter. Those palms whose trunk diameter had reached full size were included in size class III. The results of the palm census are shown in Table .

Table
Number of Palms by Oasis

Oasis	Seedling Palms (I)	Young Palms (II)	Mature Palms (III)	Total
Oasis of Mara	33	6	25	64
Twentynine Palms Inn	36	50	113	199
Fortynine Palms	8	37	53	98
Cottonwood Springs	5	10	30	45
Lost Palms	4	10	79	93
Munsen Palms	3	8	36	47
Victory Spring	0	0	2	2
Totals.	89	121	338	548

If vigorous stands should have as many or more young palms as mature palms to maintain themselves, then only the Oasis of Mara would appear to be healthy and reproducing. However, the figure for seedling palms is actually quite misleading. The majority of these seedling palms are all growing on one site. They are so crowded together that it will be impossible for more than two or three of them to ever attain maturity. Competition with each other will eliminate most of these seedlings. Therefore the Oasis of Mara would appear to be no better off than any of the other oases in this regard. The number of mature palms on this oasis has remained relatively stable over a period of many decades. A number of the older palms will probably die within the next two or three decades, and it appears that there will be no younger palms to replace them if present trends continue.

Two other oases which appear to be reproducing more vigorously than the others are Fortynine Palms and Twentynine Palms Inn. The Oasis of Fortynine Palms is certainly the most hydric of all the oases, and it has the most vigorous appearance of them all. Monument records indicate that there were 53 adult palms in Fortynine Palms at the time of its burning in 1948. The number of mature palms is exactly the same today. Man has greatly altered conditions at the Twentynine Palms Inn Oasis, and many of the young palms there may have germinated as a result of altered conditions, such as the watering of grass, earth movement and fire. It is now impossible to determine which of the palms are natural and which of them might have been planted or at least have germinated because of man's influence.

The numbers of palms in oases of the southern part of the Monument appear to be declining. Patchen(1964) cites an article by Burroughs in which the statement was made that Munsen and Lost Palms contained 170 palms in 1940. The present total figure for all size classes in Lost Palms, Munsen Palms, and at Victory Spring is 142. Thus it appears that these oases are declining, and that the future of these oases is precarious. All three of these oases have been used as a water source by the owners of the garage, service station, store, restaurant, and motel complex at Chiriaco Summit on Interstate Highway 10 (Highways 60-70) approximately 32 miles east of Indio. The water table has dropped at Lost Palms during recent years, and the flow of the spring there is no longer adequate for use as a source of water for the complex. The development of the water supply at Victory Spring appears to have been responsible for the death of one of the palms there.

There is no real basis for determining the trends at Cottonwood Oasis due to its being an artificially created oasis. It will presumably continue or perhaps even expand as long as the developed spring continues to flow at present rates. It is clear from species composition that the water table approaches the surface in several places in that oasis. It is doubtful if anyone closely observed the other species on the oasis site prior to the development of the water source. For this reason there is no valid basis of comparison which can be used to ascertain the trends in the vegetation over the period of decades encompassing the formation of the oasis.

It may not be necessary for an oasis to have large numbers of seedlings and young palms at all times if it is to maintain itself, since palms have long life spans and low mortality rates. In favorable years in which there are heavy rains over periods of several weeks large numbers of seedlings germinate in the oases of the San Andreas Fault. During these very favorable years small palm seedlings may be found in some very unlikely sites, such as the tops of sand dunes or on normally dry bajadas where there is no effective chance that the seedlings could ever survive. During such favorable periods enough palms could germinate and ultimately become established to offset the losses during unfavorable years. Mortality rates and long life spans would indicate that exceedingly favorable years need only occur once in a century to maintain the palm populations. An analysis of rainfall records reveals that such favorable periods do indeed occur more frequently than once per century. Germination of seeds and consequent production of new palms is possibly not the major reason for the drop in numbers of palms in some of the oases. Rather it is a drop in ground water levels and in the absence of suitable open areas within the oases that limit palm reproduction and endanger the future of these oases by a reduction in the number of sites which are capable of supporting palms.

Appendix A

The plant species encountered in the study of the oases of Joshua Tree National Monument are found in the following list. They are arranged by family, beginning with the non-flowering species. The flowering plants are arranged alphabetically. Each species is preceded by one of three symbols which indicates its ecological behavior. Those species which are commonly found in surrounding desert or washes or slopes are preceded by the symbol (DWS). Those species which are confined to oases and are not found in surrounding desert areas are marked by the symbol (OP) which stands for oasis proper. Those few species which are true hydrophytes are marked as (H). In addition those species which are phrae-tophytes have the symbol @ included.

Species names are followed by a series of symbols in parenthesis which denote the oasis or oases at which they are found. Plants found in the Oasis of Mara are marked with the letters OM. Those species from Twentynine Palms Inn are followed by (29I), Fortynine Palms by (49), Cottonwood Spring (CS), Lost Palms (LP), Munsen Palms by (MP), and Victory Spring by (VS). In addition those plants which are prevalent species are marked by an asterisk. The geographic areas or the classifications of the distributions of the species are indicated by symbols after the list of oases in which the plant is found. The symbols used are the same as those given in the text.

EQUISETACEAE

(H) Equisetum hymale var. robustum (49) NA

(H) Equisetum funstoni (LP) Cis

PTERIDACEAE

(H) Adantium capillus-veneris (49) NA-SA

CUPRESSACEAE

(DWS) Juniperus californica (LP) Moh

EPHEDRACEAE

(DWS) Ephedra nevadensis (OM, MP, VS) Moh-GB

AGAVACEAE

(DWS) Yucca schidigera (CS, LP) Moh-Col.

(DWS) Yucca whippleyi* (CS, LP, VS) Cis-trans

ANACARDIACEAE

(OP) Rhus trilobata (49, LP) Cis

APOCYNACEAE

(OP) Apocynum cannabium var. glaberrimum (OM) NA

BORAGINACEAE

(OP) Heliotropium currasavicum var. oculatum (291) Cis-Trans

BUXACEAE

(DWS) Simmondisa chinensis* (49, CS, LP, MP, VS) Moh-Col

CACTACEAE

(DWS) Echinocereus engelmannii (MP, VS) Moh-Col

(DWS) Opuntia echinocarpa (OM) Moh-Col

CAPPARIDACEAE

(OP) Isomeris arborea* ([illegible]M, 49, MP) Cis-Trans

CHENOPODIACEAE

(DWS) Atriplex canescens* (OM, 49, CS) Trans-GB-GP

(OP) Atriplex lentiformis (OM) Cis-Trans

(DWS) Atriplex polycarpa (OM, 29I) Cis-Trans

(OP) Suaeda torreyana (OM, 29I) Cis-Trans

COMPOSITAE

(OP) Baccharis sergiloides* (49, CS, LP, MP) Moh-Col

(DWS) Bebbia juncea* (49, LP, MP, VS) Moh-Col

(DWS) Brickellia arguta* (49, LP, MP) Moh-Col

(DWS) Encelia farinosa (MP, VS) Col

(DWS) Encelia virginensis ssp. actoni (49) Moh-Col

(DWS) Eriophyllum sp. (49) Cis

(DWS) Franseria dumosa (OM, 29I, LP) Moh-Col

(DWS) Gutierrezia microcephala* (49, LP, CS, MP, VS) Moh-GB

(OP) Haplopappus acradenius (OM, 29I) Moh-Col

(DWS) Hofmeistra pluriseta (LP) Moh-Col

(DWS) Hymenoclea salsola (OM, LP, 49) Moh-Col

(DWS) Lepidospartum squamatum (VS) Cis-Trans

(DWS) Machaerantha tortifolia (49, LP) Moh

(DWS) Pectis Papposa (OM, but an ephemeral) Moh-Col

(DWS) Peucephyllum schottii (LP, MP, VS) Col

(OP) Pluchea sericea* (OM, 29I, 49, LP, CS) Cis-Trans

(DWS) Stephanomeria pauciflora (LP) Moh-Col

(DWS) Viguiera deltoidea var. parishii* (VS, MP, LP) Col

CONVOLVULACEAE

(OP) Convolvulus longipes (MP, VS) Moh-Col

CRASSULACEAE

(DWS) *Dudleya saxosa* ssp. aloides (LP) Moh-Col

CRUCIFERAE

(OP) *Stanleya pinnata* (LP) Cis-Trans

(DWS) *Lepidium fremontii* (LP) Moh

CUCURBITACEAE

(DWS) *Cucurbita palmata* (OM) Moh-Col

FAGACEAE

(OP) *Quercus turbinella* (MP) Cis-Trans

GRAMINEAE

(OP) *Andropogon barbinodis** (49, LP, MP) WNA

(OP) *Boutelous curtipendula* (49) NA-SA

(OP) *Cynodon dactylon* (49, CS) Intro.

(OP) *Distichlis spicata** (OM, 29I, 49) NA

(OP) *Elymus triticoides* (OM, 29I) WNA

(OP) *Muhlenbergia rigens** (49, LP, MP) Cis

(OP) *Phragmites communis* var. *berlandieri* (OM) NA

(OP) *Sporobolus aroides* (OM) WNA

(OP) *Stipa speciosa* (49, MP, VS) Cis-Trans

JUNCACEAE

(H) *Juncus macrophyllus* (49) Cis-Trans

(H) *Juncus balticus* (OM, 29I) NA-Eur

(OP) *Juncus acutus* var. *sphaerocarpus* (LP, MP) Cis-Trans

KRAMERIACEAE

(DWS) *Krameria grayi* (CS, LP) Moh-Col

LABIATAE

(DWS) *Hyptis emoryi* (MP, VS) Col

LEGUMINOSAE

(DWS) *Acacia greggii** (49, CS, LP, MP, VS) Moh-Col

(DWS) *Cassia armata* (VS) Moh Col

(DWS) *Cercidium floridum* (CS, MP) Col

(OP) *Glycyrrhiza lepidota* (OM) Cis

(DWS) *Lotus rigidus** (49, LP, MP, VS) Moh-Col

(OP) *Prosopis juliflora* var. *torreyana**@ (OM, 29I, 49, CS, LP, MP) Moh-Son-Chih

(OP) *Prosopis pubescens*@ (OM) Moh-Son-Chih

LORANTHACEAE

(OP) *Phorodendron californicum** (OM, 29I, 49, LP, MP) Moh-Col

MALVACEAE

(DWS) *Sphaeralcea ambigua** (CS, VS, LP, MP) Moh-Col

NYCTAGINACEAE

(DWS) *Mirabilis froebelii* (CS) Moh-Col

ONAGRACEAE

(OP) *Zauschneria californica* ssp. latifolia* (49, CS, LP, MP) Cis

ORCHIDACEAE

(H) *Epipactus gigantea* (49, LP) Cis-Trans

PALMAE

(OP) *Washingtonia filifera**@ (OM, 29I, 49, CS, LP, MP, VS) Col

(OP) *Phoenix dactylifera*@ (CS, Introduced)

(DWS, OP) *Eriogonum faciculatum* ssp. flavoviride* (49, LP, MP, VS) Cis

ROSACEAE

(DWS) Coleogyne ramosissima* (49, LP, MP, VS) Moh-GB

(DWS) Prunus fasciculata* (LP, CS, MP, VS) Moh-Col

RUBIACEAE

(OP) Galium stellatum ssp. eremicum (LP) Moh-Col

SALICACEAE

(OP) Populus fremontii*® (OM, 49, CS) Cis-Trans

(OP) Salix exigua*® (49, LP, MP) Moh-Col

(OP) Salix lasiolepis*® (OM, 29I, 49, LP) Cis

SAURURACEAE

(H) Anemopsis californica (29I) Cis-Trans

SOLANACEAE

(DWS) Datura meteloides (OM) Cis-Trans

(DWS) Lycium andersonii* (LP, CS, MP) Moh-Col

TYPHACEAE

(H) Typha latifolia (49) NA

ZYGOPHYLACEAE

(DWS) Fagonia californica (49) Moh-Calif.

(DWS) Larrea divaricata (OM, MP, 49) Moh-Son-Chih

Appendix B

Family Composition of Oases

	% Cover	No. Species	% of Flora	IV.
OASIS OF MARA				
Palmae	6.2	(1)	3.7	6.8
Gramineae	14.9	(4)	14.8	17.1
Leguminosae	25.5	(3)	11.1	60.6
Compositae	7.5	(5)	18.5	23.8
Salicaceae	15.1	(3)	16.1	14.7
Chenopodiaceae	15.8	(4)	14.8	73.5
Juncaceae	.2	(1)	3.7	.2
Capparidaceae	.1	(1)	3.7	1.4
TWENTYNINE PALMS INN				
Palmae	35.3	(1)	6.2	88.5
Gramineae	78.9	(2)	12.5	61.9
Salicaceae	11.3	(1)	6.2	8.7
Chenopodiaceae	4.9	(2)	12.2	33.4
Leguminosae	2.9	(1)	6.2	7.4
Juncaceae	1.0	(1)	6.2	.7
FORTYNINE PALMS				
Palmae	28.1	(1)	3.1	60.2
Gramineae	9.7	(4)	12.9	38.2
Leguminosae	1.8	(2)	6.2	3.8
Salicaceae	13.3	(3)	9.4	49.3
Compositae	6.3	(8)	25.8	26.9
Equiseticeae	13.0	(1)	3.1	15.8
Chenopodiaceae	-	(1)	3.1	1.4

Appendix B

Family Composition of Oases (cont.)

	% Cover	No. Species	% of Flora	IV.
FORTYNINE PALMS (cont.)				
Polygonaceae	-	(1)	3.1	.8
Orchidaceae	0.4	(1)	3.1	.4
COTTONWOOD SPRINGS				
Palmae	20.8	(2)	9.1	40.1
Leguminosae	11.6	(2)	9.1	22.4
Compositae	3.7	(4)	18.2	30.1
Chenopodiaceae	19.2	(1)	4.5	54.3
Rosaceae	8.5	(1)	4.5	17.2
Capparidaceae	3.4	(1)	4.5	24.1
Buxaceae	-	(1)	4.5	1.0
Malvaceae	.4	(1)	4.5	4.3
Agavaceae	-	(1)	4.5	1.5
Salicaceae	-	(1)	4.5	1.1
LOST PALMS				
Palmae	25.5	(1)	2.9	30.2
Gramineae	28.1	(2)	5.9	70.3
Compositae	14.4	(1)	28.9	51.8
Salicaceae	6.6	(2)	5.9	21.8
Juncaceae	1.9	(1)	2.9	3.8
Rosaceae	-	(2)	5.9	.4
Orchidaceae	-	(1)	2.9	.03
Polygonaceae	-	(1)	2.9	1.4
Agavaceae	-	-	-	.3

Appendix B

Family Composition of Oases (cont.)

	% Cover	No. Species	% of Flora	IV.
MUNSEN PALMS				
Palmae	49.5	(1)	3.7	68.4
Gramineae	9.5	(3)	11.1	29.6
Compositae	9.8	(6)	22.2	44.8
Salicaceae	2.0	(1)	3.7	5.6
Leguminosae	1.8	(2)	7.4	7.0
Juncaceae	-	(1)	3.7	.6
Malvaceae	.7	(1)	3.7	3.0
Rosaceae	6.4	(2)	7.4	23.0
Polygonaceae	-	(1)	3.7	3.0
Labiateae	-	(1)	3.7	3.0
Capparidaceae	-	(1)	3.7	.4
VICTORY SPRING				
Palmae	26.7	(1)	6.2	87.2
Compositae	3.1	(6)	37.5	75.2
Leguminosae	-	(3)	18.8	7.5
Polygonaceae	-	(1)	6.2	1.9
Agavaceae	1.5	(1)	6.2	9.1
Malvaceae	.7	(1)	6.2	4.1
Rosaceae	-	(1)	6.2	-
Cactaceae	-	(1)	6.2	1.9

Appendix B

Family Composition of Oases (Cont.)

	% Cover	No. Species	% of Flora	IV.
VICTORY SPRING (cont.)				
Labiatae	-	(1)	6.2	1.9
Buxaceae	-	(1)	6.2	1.9
Ephedraceae	-	(1)	6.2	1.9
Agavaceae	-	(1)	6.2	9.1

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