PERPETUAL SUCCESSION OF STREAM-CHANNEL VEGETATION IN A SEMIARID REGION

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INTRODUCTION. — Riparian vegetation in its mesophytic environment in the Southwest undoubtedly uses large amounts of water, but thus far, the various species and communities associated within confines of mountain reaches have not been extensively investigated.

Flood plain vegetation of major rivers at relatively low elevations in the Southwest — the Colorado, Salt, Gila, Rio Grande, and Pecos — has been surveyed and mapped with varying degrees of intensity. Large acreages bordering these rivers, special management problems created by exotic species such as *Tamarix pentandra*[2] and *Elaeagnus angustifolia*, potential water savings by vegetation eradication, and economic value of reclaimed flood plain land, have stimulated research and management of flood plain vegetation. Recently, standardized techniques of sampling these areas have been outlined by Horton, Robinson, and McDonald (1964), which include some aerial techniques developed by Turner and Skibitzke (1952).

Shreve (1915, 1919, 1922, and 1951), Martin and Fletcher (1943), Wallmo (1955) and others, have contributed to the ecology of vegetation in Arizona, but surveys of channel vegetation along arroyos, streams, and rivers of foothills and mountains in the Southwest are lacking. No reliable estimates of area, species composition, or density of stream-channel vegetation have been made.

Whittaker and Niering (1964, 1965) give an ecological classification of the Santa Catalina Mountains of south-central Arizona following life forms deveoped by Raunkiaer (1934). Nichol (1952) discusses *Prosopis juliflora* and associated species in bosques of the desert region, but does not mention stream-bank vegetation of higher elevations. Hastings and Turner (1965) briefly consider the vegetation restricted to water courses between 4,000-6,500 feet, which they term "gallery forests." They mention that plants within this type characteristically span a greater elevational range than on adjacent uplands, and provisionally attribute this to homogenity of temperature resulting from cold-air drainage and additional moisture at all elevations. Lowe (1964) lucidly defines "riparian association" as "one which occurs in or adjacent to drainageways and/or their flood plains and which is further characterized by species and/or life-forms different from that of the immediately surrounding non-riparian climax." Lowe also recognizes that all species along a stream channel are not necessarily confined to this zone, but may be indigenous to the semiarid environment of adjacent channel slopes.

In this paper we separate riparian from the proposed term "pseudoriparian," thus making riparian of an obligate nature and pseudoriparian facultative. Pseudoriparian would apply to the woody plants capable of completing their life cycle in relatively xeric or mesic sites, but which achieve maximum size and density when additional subsurface moisture is available. For example, *Prosopis juliflora, Cercidium microphyllum, Acacia greggii, Quercus turbinella, Juniperus osteosperma,* and *Pinus edulis* found on certain sectors of Sycamore Creek, central Arizona, where the data for this study were collected would be classified as pseudoriparian. These species as well as a majority of the shrubs sampled probably become established within canyon bottoms from seed plants on adjacent slopes. Their geographical range is not extended within the channel beyond source of seed introduction. Seeds of pseudoriparian species are disseminated by wind, gravity, or animals. Obviously, the classification of flood-plain species as either riparian or pseudoriparian has limitations. Attempts to pigeonhole species often lead to oversimplification of evolutionary adaptations and complex interaction between species, but despite problems of interspecific interactions, ranges of adaptability, and frequent disturbance of stream-channel vegetation, most trees and shrubs are easily classified as riparian or pseudoriparian (Appendix I).

Concerning succession, Lowe (1964) maintains that the riparian association is not "merely a temporary unstable seral community" but should be regarded as "a distinctive climax biotic community." On Sycamore Creek, however, large-scale changes in habitats caused by recurring floods, erosion, and deposition determine to a large extent the resulting

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[2]Identification and nomenclature follows Kearney and Peebles (1960). Identifications were verified using specimens from the Arizona State University Herbarium and the U. S. Forest Service Herbarium, Forest Hydrology Laboratory, Tempe, Arizona. See Appendix I for list of common and scientific names and authorities of plants listed in text, and classification of shrubs and trees by the authors as either riparian (R), or pseudoriparian (P) species.

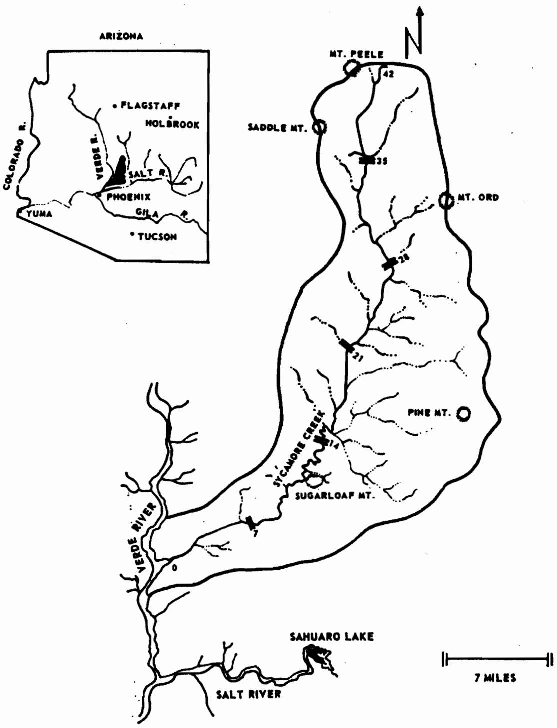

Figure 1.—Sycamore Creek watershed encompasses approximately 121,000 acres in the Mazatzal Mountains, central Arizona. The channel reach is subdivided into six approximately 7-mile lengths with a total flood plain area of approximately 3,000 acres.

vegetation complex. Because of this vegetation flux, immature stages of species development is commonplace. Our data and observations indicate this riparian association, including the pseudoriparian species, probably never reaches a climax hierarchy because of these physiographic factors.

STUDY AREA. — Sycamore Creek heads near Mt. Peele in the Mazatzal Mountains in eastern Maricopa County, Arizona, at an elevation of about 5,500 feet, and joins the Verde River some 25 miles northeast of Phoenix (Fig. 1). The Creek flows south except for the lower 8 miles of the reach, which flows generally southwest. The watershed has a total area of approximately 121,000 acres and a flood-plain area of about 3,000 acres, excluding all tributaries. Sycamore Creek is about 42 miles long. Channel gradient on the lower 21-mile sector is about 40 feet per mile. Average gradient on the upper 21-mile sector is about 155 feet per mile, with the upper 7 miles of this sector having a gradient of approximately 235 feet per mile.

The upper 21-mile sector of Sycamore Creek is in mountainous terrain primarily of granite, schist, and volcanic material, and small amounts of consolidated alluvial sediments. Small, discontinuous deposits of unconsolidated alluvial material occur along the stream channel, or in some areas the stream channel is cut on bedrock. The lower 21-mile sector of the watershed has primarily low relief and gentle slopes of consolidated alluvium consisting of sandstone, siltstone, conglomerate, and sandy clay. The channel is underlain by unconsolidated gravel, sand, silt, and clay to various depths (Thompson and Schumann, 1964). Intermittent flowing water or stagnant pools characterize the upper 21-mile sector in the spring and summer months, with continuous flow in the fall and winter. On the lower 21-mile sector in areas where the stream channel is constricted, surface water may flow only at night during summer months, presumably because evapotranspiration (ET) losses reduce flows during the day. In the deep, unconsolidated alluvium characteristic of the lower 8 miles, surface flow occurs at flood peaks but seldom reaches the Verde River.

A vegetation-type map of the Sycamore Creek watershed shows a marked change in vegetation on upland slopes at about 3,000 feet, approximately 21 miles above the Sycamore-Verde confluence (Troxel, *et. al.*, 1965). At this and higher elevations, upland slopes are dominated by chaparral species instead of desert grassland or desert shrub.

CLIMATE. — Average annual precipitation on the watershed varies between 9 inches at the Verde-Salt River confluence to 22 inches at Mt. Ord at an elevation of 7,000 feet (Fig. 1). The Mt. Ord station is located on an exposed peak, and therefore is probably influenced by prevailing high-velocity southwesterly winds, because precipitation is considerably below measurements at similar elevations on surrounding mountains. Actual precipitation at the Mt. Ord station is probably between 25 to 30 inches annually, based on a State isohyetal map of precipitation data from 1931-60. The 13-year average at Sunflower (3,500 feet) is about 20 inches annually. The ratio of summer to winter precipitation is about 40:60 throughout the reach. Late-summer convectional storms cause periodic flooding and high sediment movement, while winter precipitation is generally from low-intensity and long-duration storms, primarily in the form of rain below 4,000 feet and snow and sleet at higher elevations. Snow usually melts or sublimates within 1 day after falling, except on north-facing slopes.

METHOD. — For sampling purposes, the 42-mile reach was arbitrarily divided into 7-mile lengths, with the first sector nearest the Sycamore-Verde confluence (Fig. 1). On the 42-mile reach, 402, 0.05-acre stratified, randomly located quadrats were used to determine numbers and heights of each species of shrubs and trees. The number of quadrats on each 7-mile reach was determined statistically, depending on homogenity of dominant species. Selected quadrat size was believed to be large enough to reduce the objections posed by Greig-Smith (1964, p. 33). Slopes of adjacent canyon walls or terraces exceeding 15 percent were not sampled, and thus determined lateral boundaries of quadrat locations. Species with a frequency of less than approximately 20 percent were probably unavoidably undersampled. Supplemental data, such as d.b.h. of trees, ocular estimates of cover, site elevations, slope and aspect of canyon walls, channel slope, and surface soil type were noted for each quadrat.

One hundred and fifty permanently located 9.6-square-foot quadrats were used to estimate percent cover of forbs and grasses throughout the 42-mile reach during one summer and winter. Twenty-five quadrats on a terrace containing between 2 to 10 acres represented forb and grass vegetation on each 7-mile sector. Adequacy of this sample number was not determined statistically. Species were ranked into classes from 1 to 5, depending upon estimation of cover of each. Crown cover percent of shrubs and trees above each quadrat was recorded.

RESULTS AND DISCUSSION. — A total of 29 species of trees was recorded on the 0.05-acre quadrats on the entire 42-mile reach. Three species occurred only in the lower 21 miles, 14 only in the upper 21 miles, and 12 in both. A chi-square test suggests that differences this great might occur in the sample by chance while no real differences in composition existed between the two sectors. On empirical grounds, however, it can be stated that some species actually do occur in the upper and not in the lower, and vice versa.

Sixty-five species of shrubs were recorded on the 0.05-acre quadrats on the entire 42-mile reach (Table 1). Eight species occurred only in the lower 21 miles, 44 species only in the upper 21 miles, and 17 in both. Species found within the lower and upper areas did not occur together as often as expected by chance ($X^2 = 15.33^{**}$).

Density of shrubs was much greater on the lower sector (average 6.1 per quadrat) than on the upper (1.5). Density of trees did not differ greatly (1.4 and 1.7). Likewise, average frequency of shrubs on the lower and upper sectors was 41.7 and 29.5, respectively, while average frequency of trees was 32.5 and 35.6. Thus trees appeared to be more evenly distributed along the reach than shrubs.

High summer temperatures common to this semi-arid region cause correspondingly high potential ET

Table 1. Summary of shrubs and trees sampled on Sycamore Creek floodplain. Elevation: 1,400-5,500 feet. Density and frequency values are for plants occurring on 10 percent or more of quadrats. Density = Number plants per unit area. Circular quadrats are 0.05 acre.

Site characteristics and type	Range in elevation (feet) of six sectors						Entire area (42-mile reach)	
	1400-1550	1550-1950	1950-2250	2250-3300	3300-3850	3850-5500	Total	Average
Distance from confluence (mi.)	0-7	7-14	14-21	21-28	28-35	35-42		
Mean channel gradient (ft. per mi.)	21	57	43	150	78	236		
SHRUBS:								
Number of species	14	12	17	35	25	40	65	10.8
Average density	2.9	8.2	7.2	1.7	1.8	1.1		3.8
Average frequency	48.2	36.5	40.3	22.6	33.3	32.7		35.6
TREES:								
Number of species	6	11	13	16	15	20	29	4.8
Average density	1.1	.9	2.2	1.6	2.7	.9		1.6
Average frequency	38.7	20.0	38.7	30.3	48.1	28.4		34.1
TOTAL SHRUBS AND TREES:								
Number of species	20	23	30	52	41	60	94	15.7
Average number of species per sample	5.3	3.7	4.7	8.3	11.1	11.3		7.4
Percent cover	38	29	56	46	66	64		50.0
Number of quadrats	43	50	69	73	71	96	402	67.0

losses. However, high temperatures within the channel of Sycamore Creek are buffered somewhat by cold-air drainage, thus factor interaction causing increased available moisture may help to account for range extension of some riparian species. Some common trees of the Transition Zone (6,500-8,500 feet), such as *Pseudotsuga menziesii* and *Pinus ponderosa*, occurred along the stream channel to elevations as low as 4,500 feet (Fig. 2). *Platanus wrightii* and *Juglans major* frequently occurred within the channel proper below 3,000 feet where night temperatures were low but summer day temperatures often exceeded 100°F. Other trees common in the Upper Sonoran Zone such as *Fraxinus pennsylvanica, Sambucus mexicana, Salix gooddingii* and *Populus fremontii* are not restricted in distribution by high day temperatures. These plants occur below 1,300 feet on the Salt River flood plain where maximum temperatures frequently exceed 110°F in summer months. Riparian species of shrubs, e.g. *Baccharis glutinosa, Pluchea sericea,* and *Salix exigua* are only found on wet sites in Sycamore Canyon and, when within the Salt River Valley at elevations below 1,300 feet, on rivers and unlined canal banks. Pseudoriparian species of shrubs from the chaparral type invade the stream channel proper from adjacent canyon walls and hillsides. Once established, they neither migrate down nor upstream. Migration downstream is probably limited because transpiration exceeds maximum rate of water absorbed by roots. The limiting factor of up-channel migration is provisionally attributed to the lower winter temperatures at the higher elevations especially as influenced by cold air drainage.

Most shrub species sampled have a wider ecological amplitude than trees with respect to variation in soil moisture. Ninety-five percent of the shrub species occur on both relatively mesic and xeric sites thus classified as pseudoriparian versus only 52 percent of the trees.

In summary, riparian vegetation on Sycamore Creek does not have a distinct zonation at approximately 3,000 feet where the stream channel bisects a sharply demarked vegetation zone on adjacent canyon walls, but rather the species appear to be diffused and spread either down or up the channel. A similar conclusion was drawn on the Rio Grande in New Mexico (Campbell and Dick-Peddie, 1964). Pseudoriparian

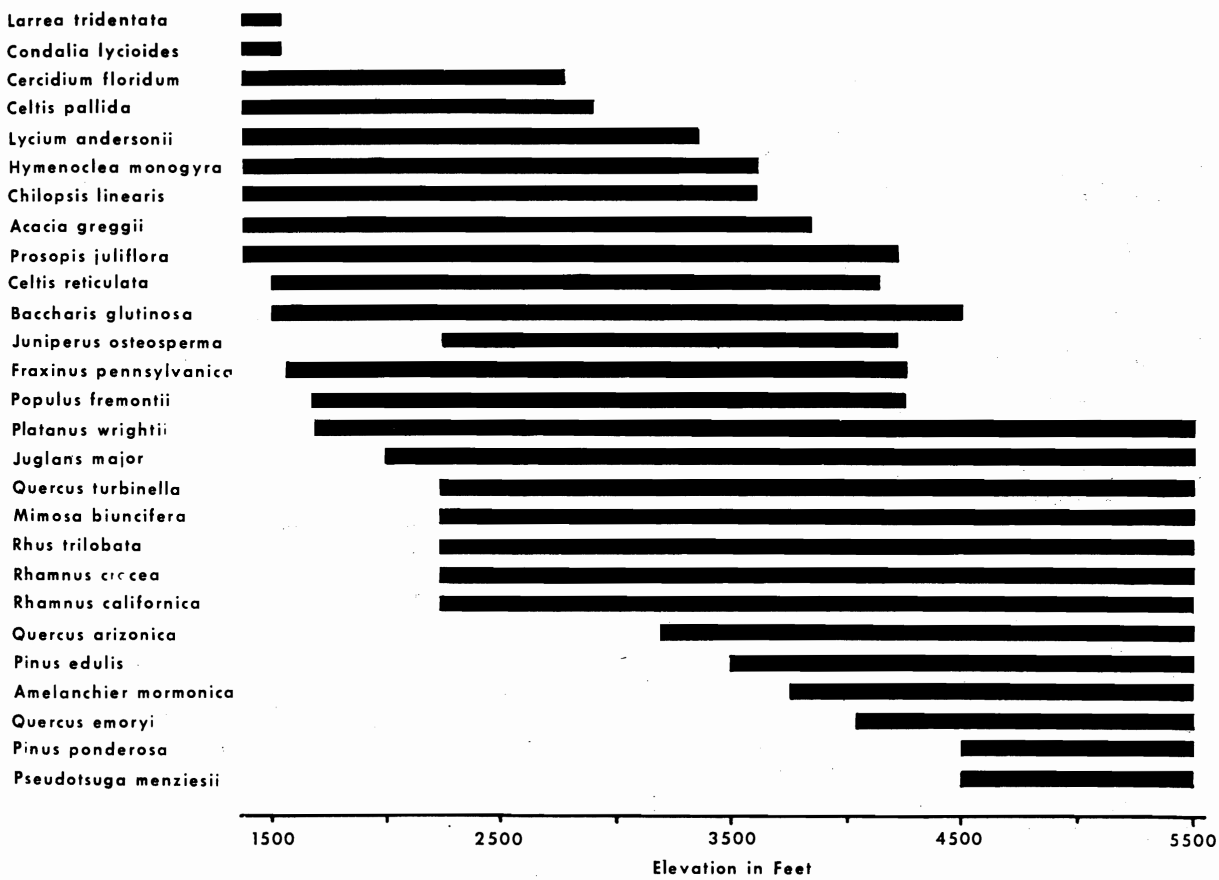

Figure 2.—Presence data showing distribution of common flood plain species in relation to elevation on Sycamore Creek. These data represent only localized conditions as they occur on this reach.

species, however, particularly the shrubs, do show this zonation along the stream channel at an elevation of about 3,000 feet.

Combined counts of forb and grass species both summer and winter are highly significant (X^2= 36.14**) between the lower 21-mile and the upper 21-mile sectors (Table 2). Of a total of 32 species sampled on the lower sector, 20 (62.5 percent) also occurred above; on the upper 21-mile sector, of a total of 95 species recorded, about 21 percent were also found below. Herbs, with the exception of aquatics, found within the channel proper were also found on adjacent slopes. Throughout the year, forbs on all sites were more predominate than grasses. Summer forbs, such as *Euphorbia* spp., *Pectis papposa,* and *Cassia bauhinioides* characterized all sites, while winter forbs, such as *Erodium circutarium, Plagiobothrys arizonicus,* and *Amsinckia intermedia* characterized the lower six sectors. In the summer, no individual grass species was common to all sectors, but *Bouteloua aristidoides* was present on the lower 35 miles of the reach. In the winter, *Schismus barbatus* was common on the lower 35 miles, with 100 percent frequency on one of the sectors.

Because of disturbances in the flood-prone channel, species form mosaics of seral stages of communities with different combinations of species dominating each stage; thus, the vegetation probably never reaches a "climax" hierarchy. Some riparian species recorded on Sycamore Creek appear to have become established primarily because geomorphological conditions influenced the microclimate. Factors such as steep, north-facing bluffs or high ridges parallel to the south of the channel reduce absorbed radiation, thus lower potential ET. Also, constrictions in the channel or a stream sector cut on bedrock, create aquifers of various size which retain water in sufficient quantities to support riparian vegetation during dry cycles. The alluvium deposited in eddies created by rocks, debris, and stream meandering often supports numerous seedlings after floods (Fig. 3). Depending on the degree of protection, one or more

Table 2. Summary of forbs and grasses sampled on Sycamore Creek floodplain. Elevation: 1,400-5,500 feet. Circular quadrats are 9.6 square feet.

Site characteristics and type data	Range in elevation (feet) of six sectors						Entire area (42-mile reach)	
	1400-1550	1550-1950	1950-2250	2250-3300	3300-3850	3850-5500	Total	Average
Distance from confluence (mi.)	0-7	7-14	14-21	21-28	28-35	35-42		
Mean channel gradient (ft. per mi.)	21	57	43	150	78	236		
GRASSES:								
Number of species —								
Summer	2	4	4	4	8	1	11	1.8
Winter	1	4	2	2	4	1	7	1.2
Present all year	0	2	0	1	3	0	4	.7
Total	3	6	6	5	9	2	13	2.2
Percent cover —								
Summer	33	3	55	36	40	13		30
Winter	7	5	11	24	15	20		14
Average number of species per sample —								
Summer	0.5	0.4	0.6	0.6	1.1	0.3		0.6
Winter	0.7	1.0	1.0	1.6	0.8	0.1		0.9
FORBS:								
Number of species —								
Summer	7	7	10	8	26	29	67	11.2
Winter	9	11	9	9	22	8	37	6.2
Present all year	1	2	2	1	7	0	9	1.5
Total	15	16	17	16	41	37	95	15.8
Percent cover —								
Summer	53	79	38	37	60	83		58
Winter	43	78	84	66	67	39		63
Average number of species per sample —								
Summer	1.6	1.5	2.0	1.6	3.8	2.9		2.2
Winter	3.6	3.5	2.5	2.4	2.7	0.4		2.5

species will inhabit the site until the stream channel changes course. Apparently, establishment of a species depends not only on its ecological amplitude, but also on chance factors such as time of year of flooding, stem-sprouting ability of the species, and viable seeds deposited on the site. Once established, factor interaction between species for light, water, or nutrients does not appear to cause major changes in species composition. More important to a species survival than competitive exclusion is its ability to recover from periodic torrential flows where stems are damaged by debris, covered by sediment, or whole plants are uprooted and redeposited farther downstream.

Vegetation communities on Sycamore Creek are not well defined or easily delineated, although some generalities can be made. In the lower 21-mile sector, the channel is bordered by 1 or more terraces 3 to 15 feet above the channel floor (Fig. 4). Species with the highest frequency in the lower 21 miles were *Prosopis juliflora, Hymenoclea monogyra, Acacia greggii,* and *Baccharis glutinosa.* The frequency of *Prosopis juliflora* tended to increase laterally away from the channel onto the first or second terrace. It developed best on the first terrace, where its deep tap root probably draws on ground-water supplies. Its degree of dependence on ground water is not known, but leaf drop has been observed on these sites when the water table was known to be more than 45 feet below the surface, presumably because of soil-moisture stress. Undoubtedly, physiographic factors such as good soil aeration and flood protection account for *Prosopis juliflora*'s higher abundance on terraces than within the channel proper. *Hymenoclea monogyra* occurred most frequently within the channel proper. Its ability to propagate from buried stems and rootstock no doubt helps to account for its success in flood-prone areas. *Baccharis glutinosa* was restricted to sites near the surface water or where ground water

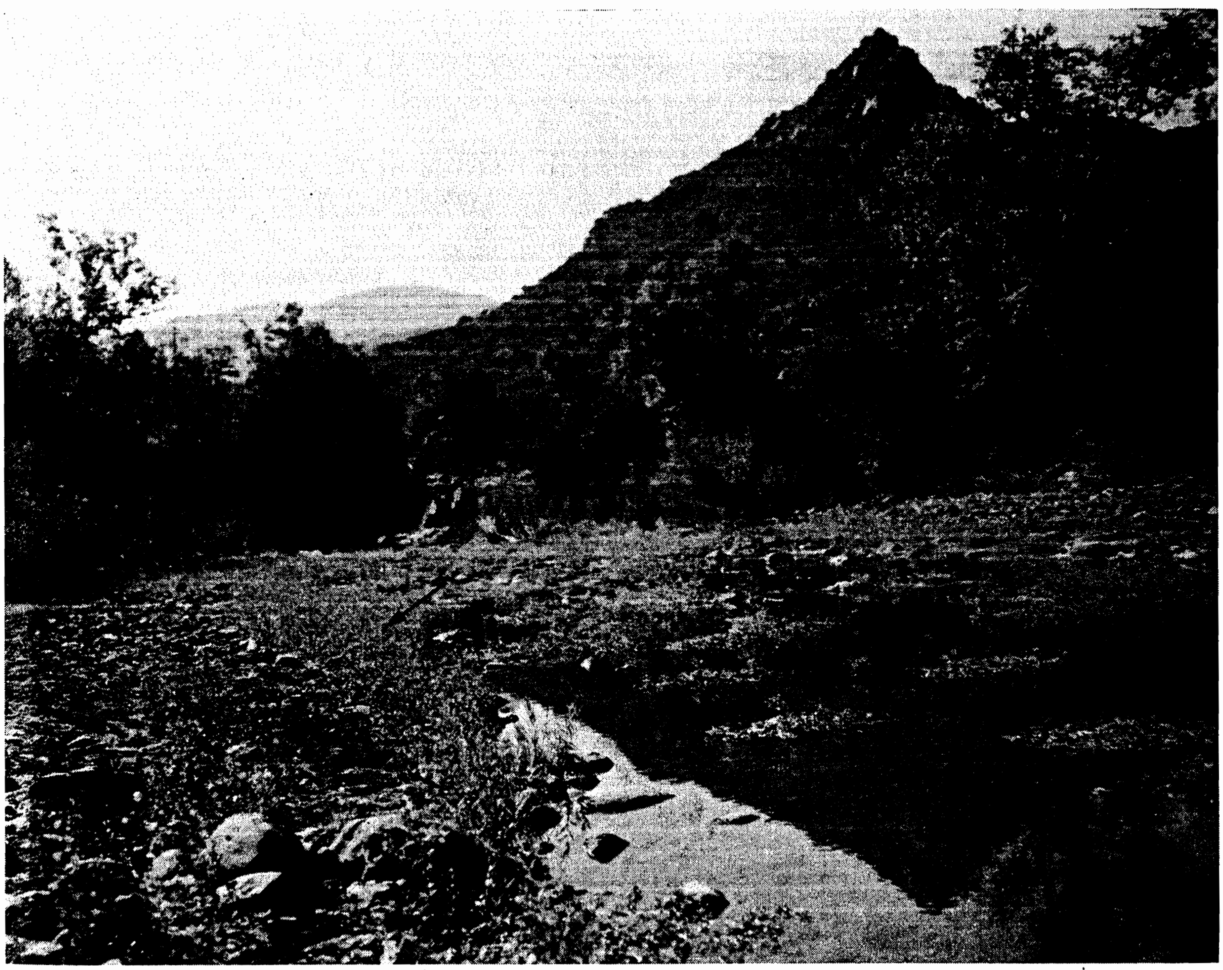

Figure 3.—Reinvasion of *Populus fremontii* and *Baccharis glutinosa* (arrow) in October following flood flows in channel of Sycamore Creek at an elevation of about 3,200 feet. High water flows frequently wash out these riparian species in this straight channel except on adjacent (protected) terraces.

was approximately 6 feet or less from the surface. Adjacent to the ribbon formed by *Baccharis glutinosa*, individuals of *Salix gooddingii, Celtis reticulata, Platanus wrightii,* or *Fraxinus pennsylvanica* were irregularly spaced, depending on degree of flood protection. Because riparian trees were taller and had a higher density than adjacent desert shrubs, trees formed a conspicuous vegetation type.

In the upper 21 miles of Sycamore Creek, *Prosopis juliflora* continued to be a common but not conspicuous species. *Acacia greggii*, associated with *Prosopis juliflora* in the lower three sectors, was replaced almost entirely by *Mimosa biuncifera*. These, as well as many shrub species common to the chaparral zone, formed a rather dense understory beneath the canopies or in the openings between *Platanus wrightii, Populus fremontii, Salix gooddingii, Juglans major, Fraxinus pennsylvanica, Quercus arizonica, Q. emoryi,* and *Cupressus arizonica* (Fig. 5). *Juniperus osteosperma,* a common but small tree, was frequently found beneath canopies of large trees.

Percentages of association between species of trees and shrubs that occur on approximately 20 percent or more of the quadrats are shown in Tables 3-7. Because of changing species, elevation, and climate, association indexes (Dice, 1945) and chi-square tests of frequency of occurrence of species were computed for each 7-mile sector. Tabular data from the second 7-mile sector have been omitted because only 4 species were sampled in sufficient numbers to be analyzed, and of these, only *Hymenoclea monogyra* and *Acacia greggii* occurred together in numbers greater than expected by chance. Species are listed in Tables 3-7 in order of decreasing numbers of occurrence to indicate their relative densities by sector. The ecological amplitude of species, geomorphological barriers, or small sampling numbers could influence values of relative densities.

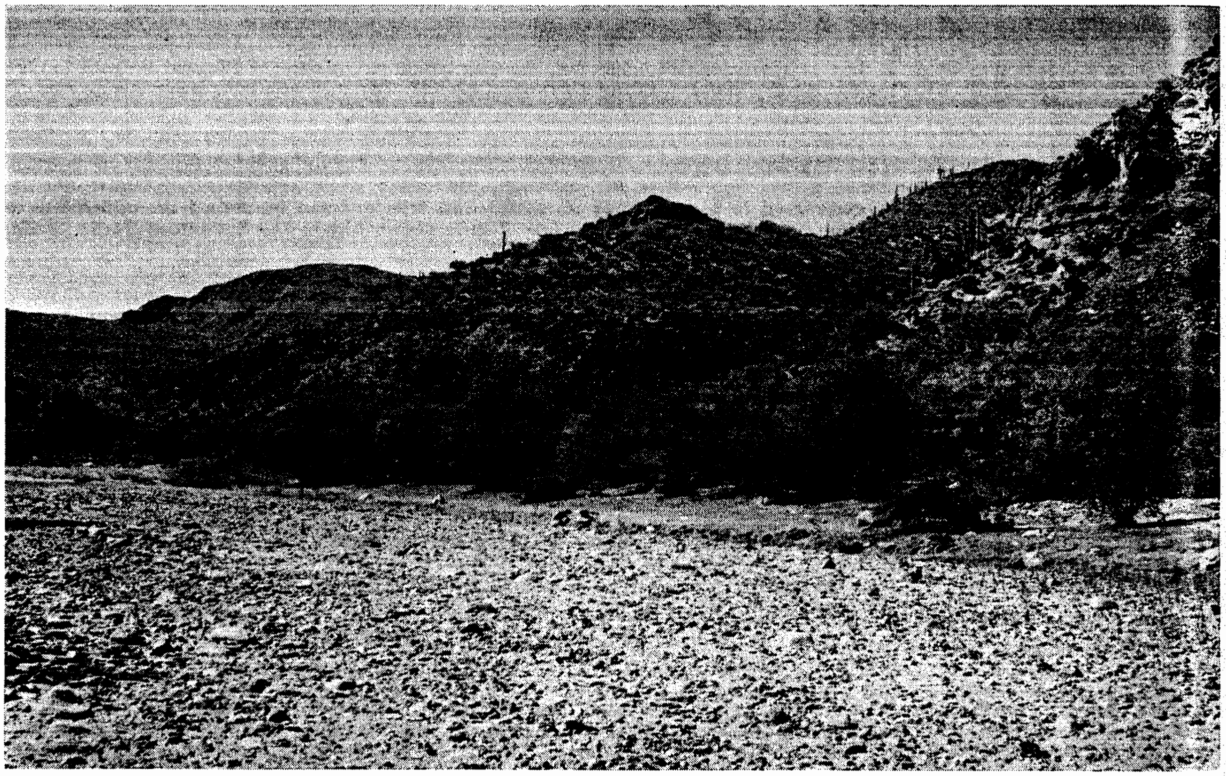

Figure 4.—Low, relatively stable stream channel on Sycamore Creek at approximately 2,200 feet containing *Cynodon dactylon* sod and mixed community of *Prosopis juliflora, Acacia greggii,* scattered *Populus fremontii* on the terrace, and *Baccharis glutinosa* along channel banks. Young *Baccharis glutinosa* dot the channel bed, but will be washed out or covered by sediment during the next flood flow.

Figure 5.—Sycamore Creek in July at approximately 3,300 feet, showing typical mixed stand of *Platanus wrightii* (a), *Populus fremontii* (b), *Fraxinus pennsylvanica* (c), and *Cupressus arizonica* (d) on a relatively stable stream channel.

Table 3. Association index converted to percentages of shrub and tree species occurring on approximately 20 percent or more of the floodplain plots in the first 7-mile sector above the Sycamore-Verde confluence. Elevation: 1,400-1,500 feet.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) *Hymenoclea monogyra*		77	81	69[1]	75	64	50[4]	80	80
(2) *Prosopis juliflora*	*71		74	88[2]	75	71	86	60	50
(3) *Acacia greggii*	65	65		54	55	64	64	60	80
(4) *Lycium andersonii*	53[1]	74[2]	52		70	64	79	50	60
(5) *Larrea tridentata*	44	48	41	54		64[1]	50	20	20
(6) *Franseria deltoidea*	26	32	33	38	50[1]		29	20	30
(7) *Condalia lycioides*	21[4]	39	33	42	35	29		30	30
(8) *Baccharis sarothroides*	24	19	22	19	10	14	21		40
(9) *Cercidium floridum*	24	16	30	23	10	21	21	40	

*The association index *Hymenoclea/Prosopis* indicates that, on 71 percent of the plots where *Hymenoclea monogyra* occurs it is associated with *Prosopis juliflora*; likewise, when *Prosopis* occurs, *Hymenoclea* occurs 77 percent of the time (Inverse Association Index, *Prosopis/Hymenoclea*=77 percent).

Greater than percentages expected from chance: [1] (P=.05), [2] (P=.01).

Less than percentages expected from chance: [3] (P=.05), [4] (P=.01).

Table 4. Association index converted to percentages of shrub and tree species occurring on approximately 20 percent or more of plots on the third 7-mile sector beginning approximately 14 miles above the Sycamore-Verde confluence. Elevation: 1,950-2,250 feet.

	(1)	(2)	(3)	(4)	(5)	(6)
(1) *Prosopis juliflora*		82	79	90	100[1]	100
(2) *Baccharis glutinosa*	78		87	90	57[4]	60[1]
(3) *Hymenoclea monogyra*	52	60		57	48	40
(4) *Salix gooddingii*	33	35	32		14	20
(5) *Acacia greggii*	36[1]	22[4]	26	14		53[1]
(6) *Celtis reticulata*	26	16[1]	16	14	38[1]	

Greater than percentages expected from chance:
[1] (P=.05), [2] (P=.01).
Less than percentages expected from chance:
[3] (P=.05), [4] (P=.01).

On the lower 7-mile sector, the association indexes (A.I.) *Lycium/Hymenoclea* of 69 percent and *Lyceum/Prosopis* of 88 percent are significant and highly significant, respectively (Table 3). Field observations indicated *Lycium andersonii* existed only beneath the shade of associated species, and preferred *Prosopis juliflora. Lycium* was recorded in sectors 2 and 3, although not in numbers great enough to be analyzed. As elevation increased, *Lycium* began to exist in open sites and be less dependent upon shade of neighboring plants. Apparently, microclimate beneath canopies of some plants on the first sector created an environment suitable for *Lycium*, and a resulting range extension of the species. Density and foliage production of many herbs also tended to increase with increased shade of the overstory. This was especially noticeable in the lower 3 sectors in the spring, when annuals exposed to full radiation died several weeks before plants of the same species growing beneath trees. The range extension of *Lycium* to lower elevations, and longer growing period of annuals beneath trees, is attributed to factor interaction of lower temperatures, which reduces transpiration by understory species and extends the period of available soil moisture.

The A.I. *Larrea/Franseria* of 50 percent was significantly greater association than by chance. Both species occupied similar ecological zones and have similar growth forms. *Larrea tridentata* apparently occupied *Franseria deltoidea* sites slightly more often than the reverse.

On the second 7-mile sector, only 4 species were recorded in numbers great enough to be analyzed, therefore the table is not reproduced. Pertinent in this sector is the significant A.I. *Acacia/Hymenoclea* of 73 percent. Apparently, *Hymenoclea monogyra* occurred on sites occupied by *Acacia greggii* more often than the reverse — the inverse association index (I.A.I.) *Hymenoclea/Acacia*, was 40 percent.

The 100 percent A.I. *Acacia/Prosopis* and the 36 percent I.A.I. (Table 4) indicates complete dependence of *Prosopis juliflora* to sites occupied by *Acacia greggii*, yet *Prosopis* had the highest density on this sector. On the fourth sector (Table 5) the same significant relationship exists between *Prosopis* and *Acacia*, with *Prosopis* again having the highest relative density. This indicates *Acacia* was limited to a more restricted range of environmental conditions than *Prosopis*, and probably on Sycamore Creek the limiting factor was available soil moisture.

Species association on the upper 21 miles of Sycamore Creek are indicated in Tables 5, 6, and 7. The problem of understanding the vegetation relationships in this area is complicated by the fact that channel flooding, scouring, and deposition continually introduce new seral stages of community developments. These disturbances within the channel are influenced by intensity and duration of rainfall, geomorphological characteristics of the watershed and channel, channel gradient, and vegetation types. For instance, in the "V" type channel near the head of Sycamore Creek and the "narrows" created by water erosion some 21 miles above the confluence with the Verde River, the occasional destructive floods create vegetation communities whose entire population is relatively immature. Presumably because of the above factors, the d.b.h. and height of trees recorded on quadrats in the upper 21-mile sector decreased with increased elevation. Riparian and pseudoriparian species (Tables 5 and 7), when significant are generally negatively associated. Riparian, or pseudoriparian species, are usually positively associated with like types. For example, in Table 5, the A.I. between a riparian and pseudoriparian species (*Fraxinus pennsylvanica/Acacia greggii*=22) indicates significantly lower association than expected by chance. The association of two pseudoriparian species (*Prosopis juliflora/Acacia greggii*=45) was significantly higher than by chance.

SUMMARY. — The community aspects of channel vegetation with respect to changing elevation on Sycamore Creek, Maricopa County, Arizona, were studied by means of association indexes of dominant species. Data were collected from 402 stratified random, 0.05-acre quadrats to determine shrub and tree composition, while 150 permanently located 9.6-square-foot quadrats were used to determine grass and forb composition. Ninety-five percent of the shrub species sampled and approximately 50 percent of the tree species are indigenous to the semiarid mountain slopes, and are not dependent upon additional subsurface moisture in the channel for survival. These species, which have a wide ecological amplitude with respect to variation in soil moisture, are termed "pseudoriparian"; they invade the channel sites perpendicularly from adjacent slopes. Pseudoriparian species remain confined to their area of introduction; they neither migrate upstream nor downstream beyond major vegetation types of adjacent slopes. The riparian

Table 5. Association index converted to percentages of shrub and tree species occurring on approximately 20 percent or more of plots on the fourth 7-mile sector beginning approximately 21 miles above the Sycamore-Verde confluence. Elevation: 2,250-3,300 feet.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) *Prosopis juliflora*		41[3]	68[1]	70[1]	82[2]	41[3]	72[1]	78[2]	75[1]	65	60	79[1]	23[4]	44
(2) *Fraxinus pennsylvanica*	38[3]		49	64[1]	39	89[2]	32[3]	52	45	95[2]	55	58	82[2]	69
(3) *Celtis reticulata*	63[1]	49		70[2]	93[2]	41	52	74[2]	95[2]	45	40	79[2]	32[3]	44
(4) *Platanus wrightii*	58[1]	57[1]	62[2]		64[2]	56	36	65[1]	70[2]	65[1]	60	79[2]	27[3]	44
(5) *Juniperus osteosperma*	58[2]	30	70[2]	55[2]		15[4]	36	65[2]	100[2]	35	30	79[2]	5[4]	25
(6) *Salix gooddingii*	28[3]	65[2]	30	45	14[4]		20[3]	39	15[3]	70[2]	45	32	68[2]	50
(7) *Acacia greggii*	45[1]	22[3]	35	27	32	19[3]		39	30	10[4]	35	26	18	13[3]
(8) *Mimosa biuncifera*	45[2]	32	46[2]	45[1]	54[2]	33	36		55[2]	45	40	47	14[3]	13
(9) *Berberis haematocarpa*	38[1]	24	51[2]	42[2]	71[2]	11[3]	24	48[2]		25	30	63[2]	5[2]	19
(10) *Baccharis glutinosa*	33	51[2]	24	39[1]	25	52[2]	8[4]	39	25		45[1]	37	36	50[1]
(11) *Aplopappus laricifolius*	30	30	22	36	22	33	28	35	30	45[1]		32	9[3]	31
(12) *Juglans major*	38[1]	30	41[2]	45[2]	56[2]	22	20	39	60[2]	35	30		18	19
(13) *Cephalanthus occidentalis*	13[4]	49[2]	19[3]	18[3]	4[4]	56[2]	16	13[3]	5[2]	40	10[3]	21		56[2]
(14) *Populus fremontii*	18	30	19	21	14	30	8[3]	9	15	40[1]	25	16	41[2]	

Greater than percentages expected from chance: [1] (P=.05), [2] (P=.01).
Less than percentages expected from chance: [3] (P=.05), [4] (P=.01).

Table 6. Association index converted to percentages of shrub and tree species occurring on approximately 20 percent or more of plots on the fifth 7-mile sector beginning approximately 28 miles above the Sycamore-Verde confluence. Elevation: 3,300-3,850 feet.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) *Juniperus osteosperma*		89	88	84	95[2]	89	94[1]	93[1]	81	95[1]	90	95	90	87
(2) *Rhus trilobata*	82		84[1]	82	84	93[2]	83	93[2]	81	78	83	90	100[2]	91
(3) *Mimosa biuncifera*	80	84[1]		80	82	85	81	84	81	81	80	80	95	87
(4) *Platanus wrightii*	75	80	79		80	83	72	81	83	70	73	65	90	78
(5) *Celtis reticulata*	85[2]	82	80	80		87[2]	72	84	74	86	77	90	95[1]	83
(6) *Quercus turbinella*	67	77[2]	70	69	73[2]		64	77	64[2]	59	57	70	86[1]	70
(7) *Opuntia engelmannii*	56[1]	54	52	47	47	50		53	55	62[1]	70[2]	65	57	65
(8) *Rhamnus crocea*	66[1]	71[2]	64	64	65	72	64		64	65	73	60	86[2]	52
(9) *Fraxinus pennsylvanica*	56	61	61	64	56	59[2]	64	63		51	60	55	62	61
(10) *Prosopis juliflora*	57[1]	52	54	47	58	48	64[1]	56	45		63	65	57	61
(11) *Berberis haematocarpa*	44	45	43	40	42	37	58[2]	51	43	51		40	43	39
(12) *Cupressus arizonica*	31	32	29	24	33	30	36	28	26	35	27		43	35
(13) *Ceanothus greggii*	31	38[2]	36	35	36[1]	39[1]	33	42[2]	31	32	30	45		30
(14) *Juglans major*	33	38	36	33	35	35	42	28	33	38	30	40	33	

Greater than percentages expected from chance: [1] (P=.05), [2] (P=.01)
Less than percentages expected from chance: [3] (P=.05), [4] (P=.01)

Table 7. Association index converted to percentages of shrub and tree species occurring on approximately 20 percent or more of plots on the sixth 7-mile sector beginning approximately 35 miles above the Sycamore-Verde confluence. Elevation: 3,850-5,500 feet.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) *Platanus wrightii*		86	85	89	85	95[2]	88	80[3]	89	96	74[4]	74[3]	87	100[1]	92	68[4]	92	87
(2) *Rhamnus californica*	65		73	76[2]	87[2]	83[1]	56[3]	76	79[1]	96[2]	97[2]	85[1]	47[4]	56	75	96[2]	96[2]	35[4]
(3) *Juglans major*	63	70		62	72[1]	65	72	74	58	79	81[1]	78	67	56	50	76	92[2]	74
(4) *Vitis arizonica*	67	75[2]	63		69	73	64	72	68	68	71	74	57	56	88[2]	72	60	52
(5) *Quercus arizonica*	62	83[2]	71[1]	67		77[2]	54[1]	74[1]	66	96[2]	84[4]	89[2]	50	56	67	84[1]	96[2]	48
(6) *Rhus radicans*	68[2]	78[1]	63	70	75[2]		56	61	74	93[2]	71	63	37[4]	40[4]	75	72	84[2]	35[4]
(7) *Quercus turbinella*	52	44[3]	58	51	44[1]	47		54	50	43	48	56	73[2]	52	33[3]	44	40	74[1]
(8) *Rhamnus crocea*	44[3]	55	55	52	56[1]	47	50		47	57	68[2]	59	47	40	38	76[2]	64	61
(9) *Amelanchier mormonica*	40	47[1]	35	41	41	47	38	39		54	39	33	33	28	33	44	44	35
(10) *Rosa fendleri*	32	42[2]	35	30	44[2]	43[2]	24	35	39		42	26	7[4]	12[3]	29	40	72[2]	13
(11) *Quercus emoryi*	27[4]	47[2]	40[1]	35	43[4]	37	30	46[2]	32	46		59[2]	20	16[1]	33	68[2]	52[1]	22
(12) *Arctostaphylos pungens*	24[3]	36[1]	34	32	39[2]	28	30	35	24	25	52[2]		33	28	33[4]	52	36	30
(13) *Mimosa biuncifera*	31	22[4]	32	27	25	18[4]	44[2]	30	26	7[4]	19	37		64[2]	17	24	4[4]	61[2]
(14) *Cupressus arizonica*	30[1]	22	23	22	23	17[4]	26	22	18	11[3]	13[1]	26	53[2]		25	16	8[3]	30
(15) *Parthenocissus inserta*	26	28	19	33[2]	26	30	16[3]	20	21	25	26	30[4]	13	24		20	16	17
(16) *Garrya flavescens*	20[4]	38[2]	31	29	34[1]	30	22	41[2]	29	36	55[2]	48	20	16	21		40	22
(17) *Robinia neomexicana*	27	38[2]	37[2]	24	39[4]	35[2]	20	35	29	64[2]	42[1]	33	3[4]	8[1]	17	40		13
(18) *Rhus trilobata*	24	13[4]	27	19	18	13[4]	34[1]	30	21	11	16	26	47[2]	28	17	20	12	

Greater than percentages expected from chance: [1] (P=.05), [2] (P=.01).
Less than percentages expected from chance: [3] (P=.05), [4] (P=.01).

species exist only where additional subsurface moisture is available in addition to annual precipitation. Riparian species are found along the stream channel in a relatively narrow band that sometimes bisects sharply demarked vegetational zones. The channel vegetation probably never reaches a climax hierarchy due to periodic flood disturbances such as erosion, inundation, and deposition. As a result, mosaics of various seral stages with different dominant species characterize the vegetation communities.

APPENDIX I

Trees and Shrubs

	Common Name	Class
Acacia greggii Gray	catclaw acacia	P
Alnus spp.	alder	R
Amelanchier mormonica C. K. Schneid	Mormon serviceberry	P
Aplopappus laricifolius Gray	turpentine bush	P
Arctostaphylos pungens H. B. K	pointleaf manzanita	P
Baccharis glutinosa Pers.	seepwillow baccharis	R
Baccharis sarothroides Gray	broom baccharis	P
Berberis haematocarpa Wooton	red mahonia	P
Ceanothus greggii Gray	desert ceanothus	P
Celtis pallida Torr.	spiny hackberry	P
Celtis reticulata Torr.	netleaf hackberry	P
Cephalanthus occidentalis L.	common buttonbush	R
Cercidium floridum Benth.	blue paloverde	R
Cercidium microphyllum (Torr.) Rose & Johnston	Littleleaf paloverde	P
Chilopsis linearis (Cav.) Sweet	desertwillow	R
Condalia lycioides (Gray) Weberb.	Southwestern condalia	P
Cupressus arizonica Greene	Arizona cypress	P
Elaeagnus angustifolia L.	Russian-olive	P
Franseria deltoidea Torr.	bur-sage	P
Fraxinus pennsylvanica Marshall	green ash	R
Garrya flavescens S. Wats.	yellowleaf silktassel	P
Hymenoclea monogyra Torr. & Gray	singlewhorl burrobrush	R
Juglans major (Torr.) Heller	Arizona walnut	R
Juniperus osteosperma (Torr.) Little	Utah juniper	P
Larrea tridentata (DC.) Coville	Coville creosotebush	P
Lycium andersonii Gray	Anderson wolfberry	R
Mimosa biuncifera Benth.	catclaw mimosa	P
Opuntia engelmannii Salm-Dyck	Engelmann pricklypear	P
Pinus edulis Engelm.	pinyon	P
Pinus ponderosa Lawson	ponderosa pine	R
Platanus wrightii Wats.	Arizona sycamore	R
Pluchea sericea (Nutt.) Coville	arrowweed pluchea	R
Populus fremontii Wats.	Fremont cottonwood	R
Prosopis juliflora (Swartz) DC.	common mesquite	P
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir	R
Quercus arizonica Sarg.	Arizona white oak	P
Quercus emoryi Torr.	Emory oak	P
Quercus turbinella Greene	shrub live oak	P
Rhamnus californica Eschsch.	California buckthorn	P
Rhamnus crocea Nutt.	hollyleaf buckthorn	P
Rhus radicans L.	poison-ivy, poison oak	P
Rhus trilobata Nutt.	skunkbush sumac	P
Robinia neomexicana Gray	New-Mexican locust	P
Rosa fendleri Crepin	Fendler rose	P
Salix exigua Nutt.	coyote willow	R
Salix gooddingii Ball	Goodding willow	R
Salix spp.	willow	R
Sambucus mexicana Presl	Mexican elder	R
Tamarix pentandra Pall.	five-stamen tamarisk, salt cedar	R

Forbs

Amsinckia intermedia Fisch. & Meyer	fiddleneck	
Cassia bauhinioides Gray	senna	
Erodium circutarium (L.) L'Her.	alfileria	
Euphorbia spp.	euphorbia	
Pectis papposa Harv. & Gray	cinchweed	
Plagiobothrys arizonicus (Gray) Greene	blood-weed	

Grasses

Bouteloua aristidoides (H. B. K.) Griseb.	needle grama	
Cynodon dactylon (L.) Pers.	Bermudagrass	
Schismus barbatus (L.) Thell.	Mediterraneangrass	

Vines

Parthenocissus inserta (Kerner) K. Fritsch	thicket creeper	R
Vitis arizonica Engelm.	canyon grape	R

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