WATER COURSE VEGETATION ON GRANITIC AND CALCAREOUS SUBSTRATES IN THE EASTERN MOJAVE DESERT, CALIFORNIA

by

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We certify that we have read this study and that it conforms to acceptable standards of scholarly presentation and is fully acceptable, in scope and quality, as a thesis for the degree of Master of Arts.

Approved by the Master's Thesis Committee

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ABSTRACT

Desert water courses are topographically distinct features with periodic flooding, which are floristically rich and structurally complex. This study was undertaken to determine if plant species and vegetation types change along desert water courses as environmental gradients are crossed. In four granitic and four calcareous water courses, vegetation patterns were classified and described for 262 samples in the eastern Mojave Desert, California. In a broad altitudinal range from mountain slope to bajada, vegetation samples were systematically taken at 300 m intervals in a 9 km distance of each water course.

A total of 15 alliances and 32 associations were delineated using Ward's method cluster analysis and Twinspan and were validated by Bray-Curtis ordination. The classification included alliances of one forest, two woodlands, two intermittently flooded shrublands, two temporarily flooded shrublands, and eight shrublands. Of these alliances, ten were at the canyon position, seven were at the arroyo position, and six were at wash position. Alliances dominated by *Acacia greggii, Chilopsis linearis,* and *Prunus fasciculata* were the most widely distributed, at more than one topographic position and on both granitic and calcareous substrates; however, these alliances had more than double the number of associations found specifically on limestone as compared to granite.

Environmental gradients showed strong relationships to the overall vegetation patterns as expressed by multi-response permutations procedures, Indicator Species analyses, and Bray-Curtis ordinations. Vegetation types appear to be expressions of moisture and temperature gradients, nutrient availability, and regional locations as

functions of aspect, elevation, geologic substrate, geographic position, surface rock cover, and topographic position. The influence of topography and geologic substrate was apparent across all watercourses. Each water course had differential species and at least one distinct alliance per topographic position, and the water courses had differential species and vegetation types depending on geologic substrate.

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INTRODUCTION

The Mojave Desert is composed of geologically diverse mountain masses that are isolated by gently sloping pediment and broad alluvial plains. This terrain is dissected by numerous water courses (Thorne et al. 1981, Norris and Webb 1990). Water courses are disturbance-dependent systems that are topographically and edaphically distinct from upland systems. While usually dry, they carry water and sediments during heavy precipitation events, and they facilitate the infiltration of water into alluvium and basin aquifers (Vogi 1995).

Particular plants are restricted to desert water courses and depend on water-induced disturbance for renewal, stimulation, and continuance (Hart et al. 1979, Castagnoli et al 1983, Smith et al. 1995, Vogi 1995). Certain vegetation types also are restricted to water courses. Water course types may have more structural complexity with frequently greater species diversity and greater perennial plant size and density than most upland types (McHargue 1973, Lang 1977, Stein and Ludwig 1979, Jorgensen and Demarais 1998, Jorgensen et al. 1995, Smith et al. 1995, Vogi 1995). Further, water courses provide important habitats for animals (Johnson et al. 1979, Thorne et al. 1981, Ford et al. 1983, Eichinger and Moriarty 1985, Mills et al. 1991, Vogi 1995, Kozma and Mathews 1997). Springs that are associated with some water courses are particularly productive and biologically rich, with a high number of endemic, rare, and endangered plant and animal species. (Johnson et al. 1979, Ford et al. 1983, Vogi 1995, Bechtel and Stevens 1996).

With knowledge of water course vegetation types, conservation and preservation of biodiversity can occur through a multi-species rather than a single-species approach. Also, the distinction in vegetation types may be explained by underlying environmental factors that control vegetation patterning. However, few quantitative studies have focused on desert watercourse vegetation patterns and environmental variation (Gardner 1951, Campbell and Green 1968, Housman 1994, Bechtel and Stevens 1996). Mountain water courses in the Mojave Desert especially have been neglected (Major 1995b).

Numerous quantitative studies exist, though, for upland vegetation and environment relationships of North American deserts. Studies in the Sonoran and Chihuahuan deserts attribute vegetation variation to geologic substrate (Aide and Auken 1985, Wentworth 1981, Parker 1988, Parker 1991) and the topographic gradient (Whittaker and Niering 1965, Klikoff 1967, Stein and Ludwig 1979, Barbour and Diaz 1973, Key et al. 1984, Wierenga et al. 1987, Bowers 1988, Parker 1988, Wondzell et al. 1990, Cornelius et al. 1991, Parker 1991, McAuliffe 1994, Valverde et al. 1986). A few studies exist for upland vegetation and environment relationships of the Mojave Desert (Beatley 1974a, Yeaton and Cody 1979, Vasek and Barbour 1995, Thomas et al. 1999).

The objective of this study is to identify and describe water course vegetation and individual plant species patterns in the eastern Mojave Desert, California. I sampled vegetation along environmental gradients of different topographic positions (mountains to alluvial fans) within contrasting geologic substrates (granite and limestone). I examined the relationships of vegetation patterning and environmental factors through classification, Indicator Species, and ordination analyses. I also compared my results to statewide efforts of classification (Sawyer and Keeler-Wolf 1995, Thomas et al. 1999).

STUDY AREA

Location

This study was conducted in the eastern Mojave Desert, primarily within the Mojave National Preserve of eastern San Bernardino County, California (Figure 1). Here I studied eight water courses, originating in four different mountain ranges and draining into surrounding alluvial fans. Desert water courses have been classified as riparian habitats with azonal vegetation (not confined to one geographical zone). They have associations of obligate plants that are different from those of adjacent upland, even though they may not contain flowing water for many years (MacMahon 1988, Rhoads 1990, Kozma and Mathews 1997, Jorgensen and Demarais 1998).

Study sites were chosen after reviewing topographic and geologic maps and after reconnaissance in the region. I located sites near access roads in drainages with similar elevation range, exposure, geologic substrate, and channel width. I selected water courses that had a broad elevation range with either south or north exposures and with either granitic or calcareous parent materials. I located two replicates of each exposure and parent material, where each granitic water course roughly corresponded in exposure to a calcareous water course.

I sampled four water courses with approximately southeast to southwest exposure from May to June 1998: The granitic Budweiser and western Willow Springs drainages in the Granite Mountains, and the calcareous northern Gilroy drainage in the Providence Mountains and south of Pachalka Spring drainage in the Clark Mountains. I surveyed four water courses with approximately northwest to northeast exposure from May to June 1999: The granitic Winston drainage in the Providence Mountains and north of New

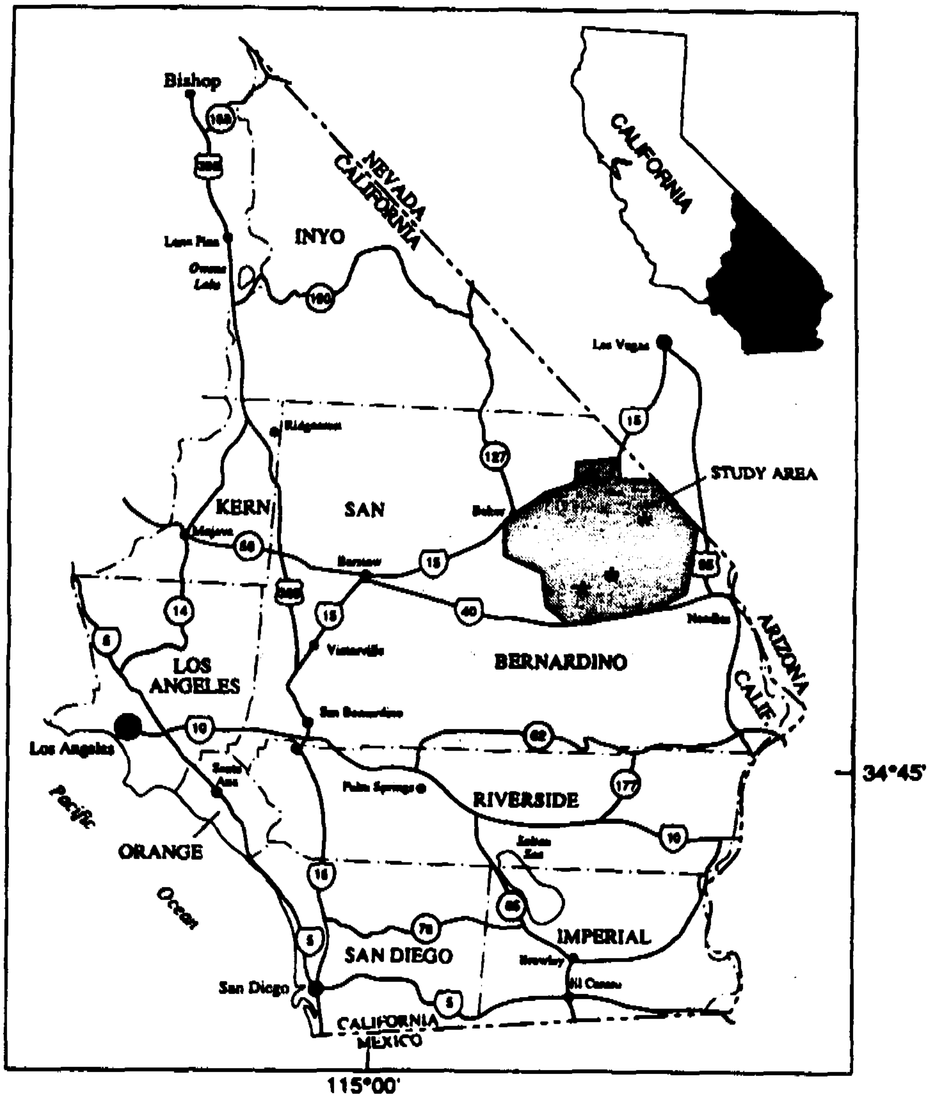

Figure 1. Location of the study area in the Mojave Desert, California. The mountain ranges in the study are starred. From south to north are the Granite, Providence, New York, and Clark mountains.

York Peak drainage in the New York Mountains, and the calcareous west of Mitchell Peak drainage in the Providence Mountains and north of Clark Mountain drainage in the Clark Mountains.

Primary access to these drainages was from interstates 15 and 40 east of Barstow, California (Figure 1). The Granite Mountains sites (Budweiser and Willow) and western Providence Mountains sites (Winston and Mitchell) were accessed from Interstate 40 about 128 km east of Barstow by travelling north on Kelbaker Road. The Clark Mountain sites (Pachalka and Clark) were accessed from Interstate 15 about 45 km east of Baker by travelling north on Excelsior Mine Road. The New York Mountains site was approached off Interstate 15 about 75 km east of Baker, heading east on Nipton Road about 6 km and then south on Ivanpah Road to about 1.2 km south of Ivanpah. Unimproved park service roads lead to the above seven sites. The Gilroy site of the eastern Providence Mountains was accessed off Interstate 40 going northeast on Essex Road. A restricted-access Mitchell Caverns State Park unpaved road lead to this site.

Climate

The Mojave Desert is classified as Hot Desert, typified by the presence of creosote bush (*Larrea tridentata*). It typically has hot dry summers and cool dry winters, with most precipitation in the form of rain (Meigs 1957, MacMahon 1988, Major 1995a). A descending subtropical high-pressure system over the Pacific Ocean primarily influences the climate. During much of the year, the air is kept dry, warm, and stable, and the sky is kept clear with intense sunlight and dry winds (Holland and Keil 1995).

The Mojave Desert receives a low amount of precipitation because the Peninsular, Transverse, Sierra Nevada, and Tehachapi ranges shield it from most winter cyclonic storms (Bailey 1975, Meigs 1957). Three weather stations in the study area have average precipitation records of about 21-25 cm annually with two rainy seasons (Figure 2, National Climatic Data Center 1999, U.C. Granite Mountains Reserve 2000). The eastern Mojave Desert has a winter peak in precipitation of around 35-50% from January to March and a summer peak of around 22-35% falling from July to September (Table 1). Precipitation is irregular and unpredictable, though, in its spatial and temporal distribution with little or no rain in some months and years. Since 1986 at the U.C. Granite Mountains Reserve in Granite Cove, extremes in precipitation have been 52.14 cm in 1992 and 9.60 cm in 1996 (Figure 3).

Temperature as well as precipitation is seasonal. While precipitation has a bimodal distribution, temperature is unimodal (Figure 4). Cooler temperatures and precipitation primarily occur in the fall, winter, and spring when vigorous storms come from westerly, Pacific Ocean airflow. Freezes can occur, but rarely in the lowlands. While rain is the usual form of precipitation, snow falls especially at higher elevations.

Clear skies, intense heating of the ground, and thunderstorms occur in the summer. Humidity is lower while temperatures are higher in mid-day summer as compared to winter. The peak temperature is in July or August with a maximum of around 27-32° Celsius. The dry air and warm summer temperatures efficiently evaporate the desert soils (Meigs 1957). Also, the range in daily temperature is greater in summer, with a nightly drop of about 17◇ Celsius (Figure 4). The thunderstorms arise from

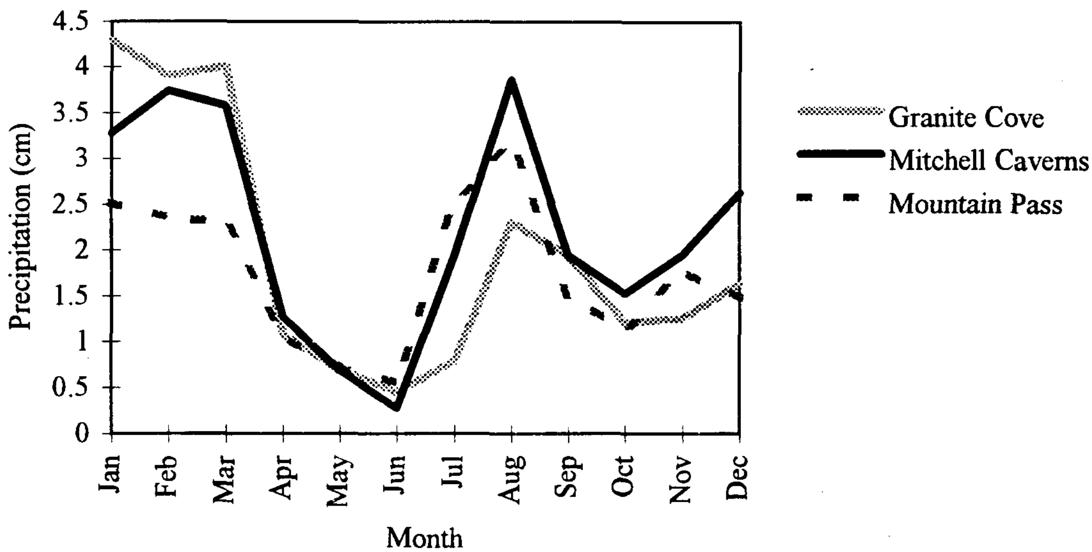

Figure 2. Monthly mean precipitation at three weather stations in the eastern Mojave Desert, California: Mountain Pass in the Clark Mountains, Mitchell Caverns in the Providence Mountains, and Granite Cove in the Granite Mountains (National Climatic Data Center 1999, U.C. Granite Mountains Reserve 2000).

Table 1. Elevation, mean temperature, and percent of mean annual precipitation in the summer and winter seasons at three weather stations in the eastern Mojave Desert, California (Major 1995a, National Climatic Data Center 1999, U.C. Granite Mountains Reserve 2000).

Station	Elevation (m)	Mean temperature (°C)			Percent of mean annual precipitation	
		Year	Jan.	July	Winter (Jan.-Mar.)	Summer (July-Sept.)
Granite Cove	1265	15	6.7	26.7	52	22
Mitchell Caverns	1319	17.2	7.8	28.7	41	30
Mountain Pass	1440	14.5	4.4	27.3	34	34

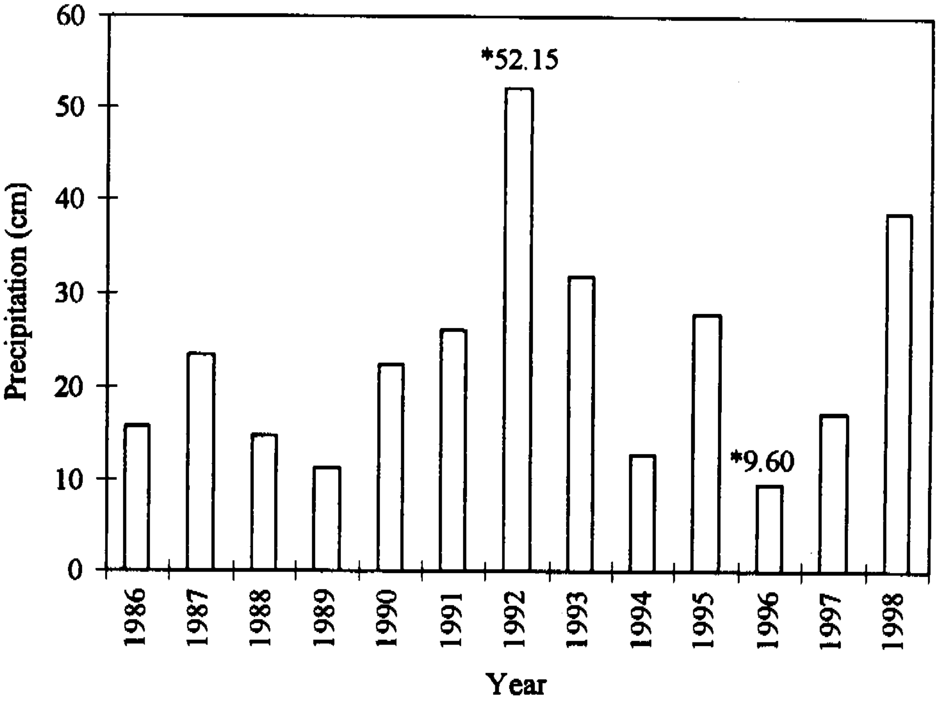

Figure 3. Mean annual precipitation at the Granite Cove weather station in the Granite Mountains, California, from 1986 to 1998 (U.C. Granite Mountains Reserve 2000). Years with the highest and the lowest precipitation are denoted by * and their values.

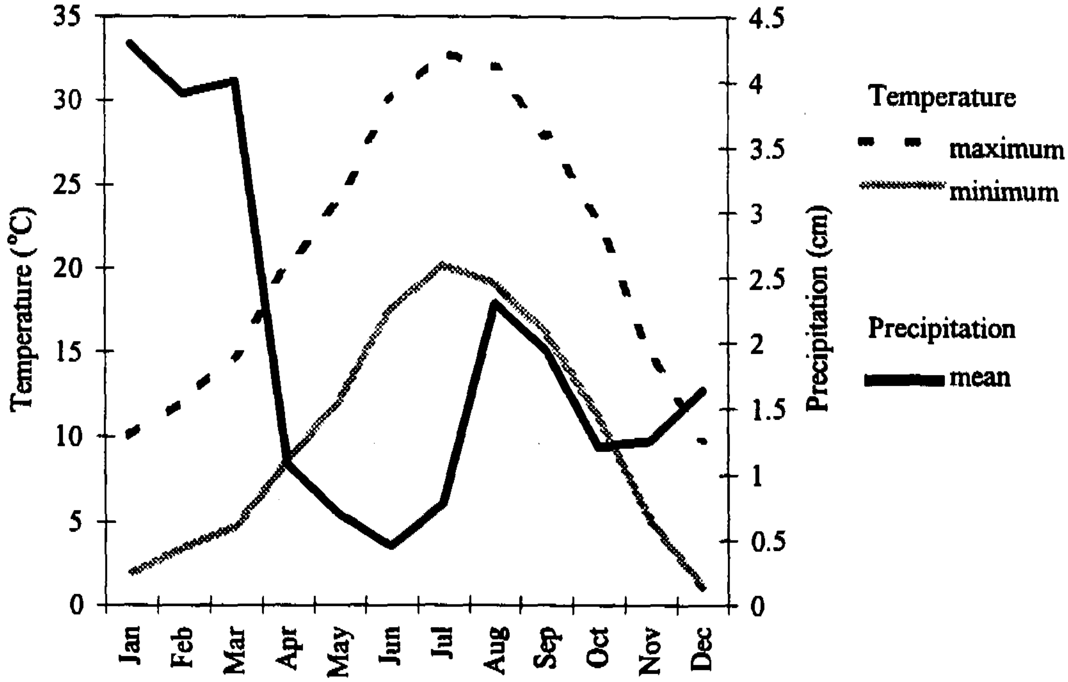

Figure 4. Monthly maximum/minimum temperature and mean precipitation at the Granite Cove weather station in the Granite Mountains, California, averaged from 1986 to 1998 (U.C. Granite Mountains Reserve 2000).

convection of humid, unstable air coming from the Gulf of California or Gulf of Mexico. They penetrate into the eastern Mojave Desert as brief, concentrated showers, which are most common in the afternoon and over mountains (Green and Sellers 1964).

Mountain masses have an effect on meso-level climate as indicated by local precipitation and temperature variations. For example, higher altitudes (up to 3000 m) receive more precipitation. Mountains obstruct the movement of air, forcing it to rise. This upslope air movement creates clouds and precipitation because the air cools by expansion and cannot hold as much water (Price 1981). On the other hand, temperature drops about 1-2° Celsius per 300 m elevation rise. Further, the large daily fluctuation in temperature of desert lowlands is probably not as large at higher elevations (Meigs 1957).

Evaporation and water availability also vary in desert mountain environments. For evaporation, a distinction is made in terms of plant growth as potential evapotranspiration (PotE). Major (1995a) calculated local PotE and precipitation lapse rates for the eastern Mojave Desert. Potential evapotranspiration exceeds precipitation for most of the year, except during winter. As a result, the biota experiences great water stress, particularly during the summer months. Since mountain areas are cooler and wetter than the desert floor, the PotE/precipitation ratio decreases with elevation rise, and soil water storage and availability increase with altitude. The arid-humid boundary (the point at which the PotE/ precipitation ratio equals 1) is at or above 2800 m, which is higher than all eastern Mojave Desert mountain ranges. However, the arid-subhumid boundary is above 1700 m, which is found in these ranges (Major 1995a, Thorne et al. 1981). Thorne et al. (1981) list canyon bottoms, north-facing draws, seeps, and springs also as subhumid because they have saturated soils or free-flowing water.

The solar radiation that mountains and lowlands receive is dependent on latitude, time of year (height of sun), slope orientation, and slope angle. For example, higher latitudes have longer summer daylight and shorter winter daylight than lower latitudes. Also, every slope has a different potential for receiving sunlight. In the Northern Hemisphere, north-facing slopes receive less solar radiation during the day and are colder than south-facing slopes, particularly in summer. This is especially true for steep north-facing slopes, where less/no direct light is received. Further, a 30° south-facing slope receives more solar radiation during the day than no slope (Price 1981).

To summarize, the eastern Mojave Desert has a variety of local climates that range from arid to subhumid. While a considerable amount of precipitation falls in the winter, a substantial amount also comes in summer. Winters may have snowfall and freezing temperatures, while summers have warmer temperatures and larger fluctuations in daily temperature. The winter season may allow for some storage of soil water, particularly along water courses and north-facing slopes, because of sufficiently low temperatures and high humidities.

Hydrology

The study area has a drainage network that consists of water courses on hill slopes that connect to washes on alluvial fans. Small water courses on steep, upper mountain slopes become more prominent on lower slopes as canyon bottoms, and they open to broad washes on alluvial fans. They occupy a topographic position where they collect run-off water from mountain slopes in precipitation events (Meigs 1957, Hart et al. 1979, Ludwig and Whitford 1981, Castagnoli et al. 1983). Storm waters rush down mountainsides, and collect in mountain channels. With immense erosive force and transporting ability, the waters carry quantities of debris, rocks, and sand outside canyon mouths in sheetflows and channels. In strong storms, water is transported in lowland washes to basins that replenish groundwater aquifers. During much of the year, though, these watercourses are dry (Jaeger 1957).

A clustering of springs and seeps occur in the major mountain areas of the eastern Mojave Desert and are relatively absent in lowland areas. They occur particularly in granitic bedrock such as in the Granite and Kingston mountains where water is forced to surface due to granite's nature of faulting and fracturing, and pools are formed (Cahn and Gibbons 1979, Reneau 1983).

Landforms and geology

Regional geomorphology

The Mojave Desert is a landlocked province of Cenozoic age (Norris and Webb 1990). This desert presumably was formed from movements related to the San Andreas and Garlock faults and their predecessors perhaps as early as the Oligocene. It is enclosed on the southwest by the San Andreas fault and the Transverse Ranges and on the north and northeast by the Garlock fault, the Tehachapi Mountains, and the Basin and Range. However, its other boundaries are more arbitrary, with portions of southern Nevada and western Arizona along its eastern boundary. The San Bernardino County line is its southern boundary (Norris and Webb 1990).

Common landforms in the Mojave Desert are mountains, alluvial fans and bajadas, pediments, drainages, and playas. Broad alluviated basins dominate the region, which are surfaces receiving continental alluvial deposits from adjacent uplands. Norris and Webb (1990) express the landforms as "Throughout the Mojave, small hills rise above the alluvial valley fill, islandlike in seas of gravel. These are remnants of the mountainous topography that is partly erased by erosion or buried by debris."

Mountain ranges rise abruptly from the surrounding surfaces. Most mountains have elevations between 1050 and 1500 m, but ranges in the eastern and northern corner have a larger and consistent elevation change. These eastern and northern ranges of the Mojave are roughly north-south in orientation. One chain of mountains in the eastern Mojave extends northeasterly from the Granite Mountains to the Providence Mountains and Midhills to the New York Mountains and finally to Nevada's McCullough Range which has a number of peaks near 2100 m. North of this chain is the highest mountain group extending north-south from the Ivanpah Mountains to the Mescal and Clark Ranges, with the highest peak Clark Mountain at 2418 m (Norris and Webb 1990).

Pediment is a term used for flat or slightly concave upward erosional rock surfaces underlain by bedrock that is partially covered by a thin veneer of alluvium (Dohrenwend 1987). Pediments form aprons around mountain fronts, especially forming on deeply weathered, coarse-crystalline granitic bedrock. Extensive pediment surfaces cut across northwest-trending mountains of the eastern Mojave Desert (Dohrenwend 1987, Dorn and Meek 1993), such as at my granitic water course sites.

Alluvial fans are ubiquitous landforms of the Mojave Desert. They are elongate depositional features of water and gravity-moved sediments that radiate downslope from mountains in grades less than 7.5°. Alluvial fans merge to form alluvial slopes, whereby coalescing alluvial fans are termed bajadas (Dohrenwend 1987). The bajadas are composed of heterogenous alluvium, which varies from coarse-textured in upper bajadas and finer-textured in lower bajadas.

Water courses reflect the overall physical characters of the surrounding topography, traversing every type of the terrain from mountain peaks to lowland alluvial fans (Castagnoli et al. 1983). In the mountains, water courses have confined channels that form canyon bottoms. The upper alluvial fans at canyon mouths are deeply cut by water courses, called arroyos. The lower alluvial slopes are usually gentler and more shallowly incised by water courses, called washes. Washes form dendritic or reticulate patterns in young and old alluvium (Thorne et al. 1981, McHargue 1973). Drainage ends in interior basins, which contain at least one intermittently wet old lakebed, or playa (Norris and Webb 1990).

Regional geology

In the eastern Mojave Desert, geologic formations are complex because of thrust folding and faulting, extension and compression, and sinking and uplifting (Thorne et al. 1981). Geologic formations range from Proterozoic age, over 600 million years ago (Ma), to Holocene age, within the last 10,000 years. They include metamorphic, sedimentary, and extrusive and intrusive igneous rocks (Norris and Webb 1990).

Marine sedimentary strata are extensively exposed in the eastern Mojave Desert (Leventhal 1979). This region sunk down and was shallowly submerged by the Pacific Ocean during the Paleozoic Era, from 600 to 230 Ma. One of the thickest Paleozoic marine sections in the Mojave is exposed in the Providence Mountains, with a total thickness about 3000 m (Norris and Webb, 1990). Marine deposits also comprise the main mass and northeastern part of the Clark Mountains (Thorne et al. 1981).

All Paleozoic sediments in the Mojave are marine, mostly calcareous (limestone and dolomite), some shale, and very little sandstone (Norris and Webb 1990). Limestone is derived from lithified shells and skeletons of foraminifera and other organisms that secrete calcium carbonate extracted from seawater. It primarily is composed of calcium carbonate in the form of mineral calcite, and weathers to calcium and bicarbonate ions. Dolomite is formed by chemical alteration of limestone (Easterbrook 1993, Press and Siever 1994).

Mesozoic geology is dominated by subduction of the Farallon and/or Kula plates beneath the North American Plate. Subduction has resulted in a continental-margin magmatic arc of considerable igneous activity in the California Mojave Desert. Granitic plutons of this magmatic arc are widespread and abundant in approximately northwest-trending belts, primarily made up of Nevadan granitic intrusives. They can be divided into three major age groups: Late Permian-Early Triassic, Jurassic, and Cretaceous. Jurassic rocks especially outcrop in the Providence Mountains area, while Cretaceous rocks extensively outcrop in the Granite and New York mountains (Fox and Miller 1990, Norris and Webb 1990).

Granite usually contains about 70% silica, with quartz, potassium feldspar, and sodium-rich plagioclase feldspar abundant (Press and Siever 1994). In general, eastern Mojave plutons are silicic (Norris and Webb 1990). Granite weathers to silica, potassium carbonate, clay of aluminum silicates, and other minerals (Easterbrook 1993).

Geology of the study sites

Four of my eight canyon water courses have calcareous geologic substrate (Table 2). In the Providence Mountains, the upper Mitchell canyon and entire Gilroy canyon have limestone rocks of Devonian, Mississippian, and Permian age. The Mitchell canyon also has Cambrian dolomite in its mid to lower section; outside of this canyon, the alluvial arroyo has steep siliciclastic rock walls. These walls are bedded quartzitic rocks or interbedded limestone, siltstone, and shale. In the Clark Mountains, the Clark canyon has the same pattern of limestone, dolomite, and siliciclastic rock walls. Lastly, the Pachalka canyon site has Cambrian dolomite, and the alluvial arroyo outside this canyon has steep walls of siliciclastic rock (Miller et al. 1991).

Four canyon water courses have granitic geologic substrate (Table 3). The northern Granite Mountains and southern Providence Mountains have a mixture of Jurassic plutonic rocks dating near 165 to 155 Ma. Most of the Jurassic intrusive rocks are compositionally (mafic to felsic) and texturally heterogeneous. The Budweiser site has some quartz diorite gneiss in its uppermost section. The Winston canyon site has

Table 2. Calcareous rock units in the study area (Bishop 1964, Healey 1973, Miller et al. 1991).

CALCAREOUS ROCKS

PROVIDENCE MOUNTAINS AND CLARK MOUNTAINS -- Late Proterozoic to Paleozoic

Dolomite of Cambrian age – middle Mitchell canyon, Pachalka canyon entirely, Clark mid to lower canyon and parts of alluvial arroyo.

Dolomite of the Nopah and Bonanza King formations.

Thin-bedded, buff and gray.

Argillaceaous in lower part.

Limestone of Devonian to Permian age – upper Mitchell canyon, Gilroy canyon entirely, upper Clark canyon.

Limestone of Pennsylvannian Bird Spring, Mississipian, and Monte Cristo formations; limestone and dolomite of Devonian Sultan Formation.

Thick-bedded, cherty, sandy, pure; massive, pure, coarse, and cherty in lower section; medium-bedded.

Siliciclastic rocks of Late Proterozoic to Cambrian age – parts of Mitchell, Pachalka, and Clark alluvial arroyos.

Marine sedimentary and metasedimentary rocks: Interbedded limestone, siltstone, and shale in upper part of unit; quartzitic rocks in lower part.

Table 3. Granitic rock units in the study area (Bishop 1964, Healey 1973, Miller et al. 1991).

GRANITIC ROCKS

GRANITE MOUNTAINS – Jurassic
Quartz diorite gneiss – interspersed in uppermost section of Budweiser canyon.
Metamorphic gneiss of quartz diorite and quartz monzodiorite.
Dark-colored with megacrysts of potassium feldspar with hornblende.

GRANITE MOUNTAINS – Cretaceous
Porphyritic monzogranite – Budweiser canyon and upper to middle Willow canyon. Small outcrops in Budweiser alluvial arroyo.
Porphyritic mozogranite.
Coarse-grained and light-gray with potassium feldspar phenocrysts and biotite.

Granodiorite – small outcrops of lower Budweiser canyon walls.
Equigranular granodiorite.
Hornblende and biotite.

Equigranular monzogranite – lower Willow canyon, small outcrops in Willow alluvial arroyo.
Equigranular rocks of monzogranite.
Medium-grained with biotite.

PROVIDENCE MOUNTAINS– Jurassic
Quartz syenite of Winston Basin – upper Winston canyon.
Markedly porphyritic rocks consisting of quartz syenite, syenogranite, and monzogranite.
Coarse-grained and melanocratic (pink to purple phenocrysts), with augite, hornblende, and biotite.

Quartz monzonite of Goldstone – lower Winston canyon.
Porphyritic and subequigranular rocks dominated by quartz monzonite, but including quartz syenite and quartz monzodiorite.
Medium- to coarse-grained and dark-colored; mafic rocks phases contain biotite, horneblende, and augite.

NEW YORK MOUNTAINS – Cretaceous
Mid Hills Adamellite – upper to lower New York canyon.
Porphyritic to equigranular rocks of monzogranite.
Medium- to coarse-grained, light-tan; magmatic dikes and hornblende locally present.

heterogeneous equigranular mixed plutonic rocks that grade into porphyritic mixed rocks (Fox and Miller 1990).

The Jurassic plutons are intruded by Cretaceous plutons, and these younger plutons are more homogeneous. The eastern and western Granite Mountains have Cretaceous age rocks, which are about 150-170 Ma (Table 3). The rocks primarily range from granodiorite to equigranular and porphyritic monzogranite (Fox and Miller 1990). The New York Mountains also have Cretaceous age granite and are part of the Cretaceous Teutonia batholith with shallowly emplaced plutons dated at about 93 Ma. Monzogranite is found over much of the central New York Mountains, including the canyon of the New York site (Miller and Wooden 1993).

The eight water courses studied cut across alluvial fan deposits of poorly sorted gravel, sand, and silt that are mostly of Holocene age (Table 4). Along the mountain-sides, the water courses cut across some older Pleistocene and Pliocene age deposits. The older deposits are underlain by raised, paved, and desert-varnished surfaces, and/or they locally contain extensive pedogenic calcite, or caliche layers. These consolidated banks especially occur in the arroyos of the New York Mountains and all three Providence Mountains sites.

In summary, four water courses have calcareous substrates, mainly limestone and dolomite, that have formed over 240 Ma. Four younger water courses have silicic, granitic substrates, aging about 90 to 170 Ma.

Table 4. Sedimentary deposits in the study area (Bishop 1964, Healey 1973, Miller et al. 1991).

NONMARINE, SEDIMENTARY DEPOSITS

ALL SITES - Quaternary

Pleistocene and Pliocene gravel – New York, Winston, Mitchell, and Gilroy alluvial arroyo walls.

Moderately consolidated pebble, cobble, and sand deposits, usually highly incised.

Locally contains extensive pedogenic calcite.

Pleistocene nonmarine sedimentary deposits – upper Winston wash, Pachalka alluvial arroyo, and Budweiser alluvial arroyo and wash.

Older, elevated, and dissected alluvium of sand and gravel deposits.

Local terrace deposits.

Pleistocene and Holocene alluvial fan deposits and alluvium – all sites.

Poorly sorted gravel, sand, and silt of valley and stream alluvium.

Older deposits along mountainsides underlain by raised, paved, and desert-varnished surfaces.

Locally overlain by a thin veneer of aeolian sand.

METHODS

Sampling

I initiated sampling within a mountain headwater tributary of each water course using the following criteria: The channel was active, channel width was at least 5 m, the channel vegetation was compositionally different from the surrounding upland vegetation and included locally obligate water course plants (e.g. *Fallugia paradoxa*), plants occupied at least one percent of the total ground cover, and the parent material was primarily granite or limestone. An active channel is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. This break in slope also coincides with the lower limit of permanent riparian vegetation. (Rhoads 1990). I followed one active branch of each water course using this criteria.

I took samples systematically at 300 m intervals for 30 locations down a 9 km distance of each water course. At each location, I established one to three samples. If the vegetation at a location was conspicuously heterogeneous, I took up to three samples. Every sample encompassed a homogeneous stand of vegetation. Homogeneous stands are based on the "general visual impression" of homogeneous vegetation structure and composition and uniform environmental conditions within the sample (Gauch 1982).

Samples were 1000 m^2 in size and varied in shape from 5×200 m to 10×100 m, depending on the width of the water course at the location. I defined the width by the distance across the water course inside its active channel banks as I recognized channel banks by their steep change in angle from the incised channel bottom. If banks were not apparent, I used the presence of obligate water course plants in a stand to identify the channel width. If the water course was more than 10 m wide, I randomly chose a 10 m section within the water course banks. Each sample followed the linear curvature of the water channel.

Field sampling methods were adapted from Thomas et al. (1999). I identified all perennial vascular plants and all annual exotic vascular plants in each sample, and I gave them estimates of cover in height classes for species composition datasets. Taxonomic nomenclature is consistent with *The Jepson Manual* (Hickman 1993). A species list is included in Appendix A, and plant codes used in the species composition datasets and common names of plants are in Appendix B. Annual plants were recorded but not used in analyses because their cover widely fluctuates seasonally and yearly (Went 1948, Beatley 1974b). I identified non-vascular plants through the main categories of moss, crustose lichen, and cryptogammic crust. I deposited voucher specimens of unknown plants at the University of California Granite Mountains Reserve Herbarium once they were identified.

To increase sampling efficiency, I made ocular or visual estimates of species cover, species structure, and environmental variables. I assigned each plant species an ocular estimate of percent canopy cover. I then translated these percent cover values into modified Braun-Blanquet coverage class values (Table 5) (Barbour et al. 1980, Daubenmire 1968). I estimated cover as the "percentage of the ground included in a vertical projection of imaginary polygons drawn about the total natural spread of foliage of individuals of a species" (Daubenmire 1968).

Table 5. Criteria to establish coverage class values for sampling.

Abundance	Range of Coverage, %	Coverage Class Value
Rare	<1	1
Occasional	1-5	2
Intermittent	5-15	3
Common	15-25	4
Moderately dense	25-50	5
Semi-continuous	50-75	6
Continuous	75-100	7

I assessed plant structure for the vascular plants using three vertical height classes. I placed all species coverage values into the appropriate vertical height classes: ground (<0.5 m), shrub (0.5-3.0 m), and tree (>3.0 m). A single species may be represented in more than one vertical layer in a sample, depending on its height. I assigned the coverage values of non-vascular plants to the ground height class. I also recorded total vegetation structure for each sample. I combined coverage of all species in each vertical height class for total ground, shrub, and tree coverage, and combined the three height classes to assess total vegetation coverage (see Appendix C for codes used in datasets). Overlap of species was disregarded in these estimates.

I assessed the following environmental variables: 1) degree aspect, using a compass; 2) degree slope, using a compass; 3) elevation, using a Global Positioning System (GPS), altimeter, and USGS 7.5 minute topographic maps; 4) microtopography, i.e. concave, undulating; 5) topographic position, i.e. canyon bottom, arroyo, wash; 6) Universal Transverse Mercator (UTM) coordinates, using a GPS and topographic maps; 7) width of wash, using a tape measure and by pacing; 8) geologic substrate, i.e. granitic or calcareous; 9) rock/sediment composition at ground surface; 10) soil texture. I transformed degree aspect into a ranked classification (Table 6), following research of upland desert slopes (Wentworth 1981, Whittaker and Niering 1965, Haase 1970). I changed degree slope into percent slope by converting the 90 degrees to a 100 percent scale. I described topographic position by the landform that each water course traversed. I defined canyon bottom, or canyon, as an erosional feature confined within the bedrock of a mountain range. An arroyo is partly depositional and partly erosional, found directly

Table 6. Ranked classes for aspect.

Class	Degree Aspect	Degree Aspect
1	N, NNE	0-30°
2	NE	30-60°
3	ENE, NNW	60-90°, 330-360°
4	E, NW	90, 300-330°
5	ESE, WNW	90-120°, 270-300°
6	SE, W	120-150°, 270°
7	SSE, WSW	150-180°, 240-270°
8	SW	210-240°
9	S, SSW	180-210°

beyond the mountain on alluvium bounded by high alluvial walls (>3 m) and/or underlain by pediment. A wash is a depositional feature in shallow incised (<3 m walls) channels.

I estimated the approximate percent cover of rock/sediments and plants at the soil surface with the following categories: fine (<3mm), gravel (>3mm, <76mm), cobble (>76mm, <25cm), stone (>25cm, <61cm), boulder (>61cm), bedrock, plant basal area (area at soil surface), and litter (woody debris). The percent cover values were translated into a cover class index (see Table 5). The codes for rock/sediment composition used in analysis are in Appendix C. I also recorded the soil texture of the upper soil horizon. I mixed a handful of soil with water to make a thick paste, and assessed the soil texture using the methodology of Brewer and McCann (1982).

Data analyses

Since my sites are positioned along a topographic gradient (canyon, arroyo, and wash), I used a direct gradient approach to evaluate the change in species composition and environmental variables in the four granite and four limestone water courses. I computed total species richness for each water course, mean species richness for the three topographic positions of each water course, and mean percent cover of species (in the categories of tree, shrub, ground, and non-native) for the three positions. I also assessed the variation in elevation, slope, and mean percent cover of rock/sediments for the three topographic positions. I used a two-sample *t*-test to determine whether sites on granite and limestone sites significantly differed in rock/sediment cover. I used the Mann-

Whitney U test and the Kolmogorov-Smirnov test for differences in means for when the assumption of normality was not valid.

I used multi-response permutation procedures (MRPP) to directly test the effects of both geologic substrate and topographic position on species composition (Meilke *et al.* 1981). I used Indicator Species analysis to detect the value of different species for indicating geologic substrate and topographic position (Dufrêne and Legendre 1997).

In addition, I performed an indirect, complementary analysis of classification and ordination to analyze the species composition and environmental datasets. When both analyses present similar results, they substantiate each other and provide a robust analysis (Gauch 1982). Classification methods assign samples to different groups, or vegetation types, based on similarities and differences of species abundances. I used cluster analysis of Ward's minimum variance method (Ward 1963) and two-way indicator species analysis (Twinspan) (Hill 1979) to objectively classify the samples. Ordinations identify groups of samples based on their similarity of species composition and/or environmental controls (Gauch 1982, Kent and Coker 1992). I chose Bray-Curtis or polar ordination to arrange samples in species space (Bray and Curtis 1957). Further, I performed Indicator Species analysis on the Twinspan and Ward's method groupings to find appropriate clustering levels with indicator species (Dufrêne and Legendre 1997).

I performed these analyses in PC-ORD (McCune and Mefford 1997) and two-sample *t*-tests and Ward's method in NCSS 2000 (Hintze 1999). Before beginning the analyses, I removed rare species that occurred in less than 5% of all the samples to reduce skewness and heterogeneity of the datasets. Also, I performed outlier analysis (McCune and Mefford 1997) to remove "outlier" samples, using both Sørenson [1-2W/(A+B)] and Euclidean distances. I removed any sample that had a standard deviation at least 3.0 away from the mean and that was separated from other samples.

I performed the analyses on the following species composition datasets: 1) the complete dataset of eight water courses at all topographic positions (one with vertical height classes separated and another with height classes combined); 2) the dataset of eight water courses at the canyon position with height classes combined; 3) the dataset of eight water courses at arroyo and wash positions with height classes combined. I used a second environmental dataset containing the following: species richness, vegetation structure of the three vertical height classes, and environmental variables.

Multi-response permutation procedures (MRPP)

MRPP is a non-parametric method for testing multivariate differences among pre-defined groups. It is similar to the parametric methods of Discriminant Analysis and *t*-tests, yet has an advantage of not requiring assumptions such as multivariate normality and homogeneity of variances (Zimmerman et al. 1985, Biondini et al. 1985). A null hypothesis of no effect on species composition between granite and limestone sites was tested. A second null hypothesis of no effect on species composition between different topographic positions was tested. Since topographic position has more than two groups, I first analyzed the species composition data first with all groups included (i.e. analysis for canyon, arroyo, and wash). Then I reanalyzed the data with one group excluded (i.e.

analyses for canyon and arroyo, canyon and wash, and arroyo and wash) to elucidate which group or groups were responsible for a significant effect.

I selected the Euclidean distance measure and n/sum(n) weighting factor. The test statistic describes the separation between the groups. The observed delta (the average within-group distance) is compared to an expected delta, the latter representing the mean delta for all possible partitions of the data. The probability (*p*) value expresses the likelihood of getting a delta as extreme or more extreme than the observed delta, given the distribution of possible deltas (McCune and Mefford 1997). I accepted a *p* value of below 0.01.

Indicator Species analysis

This method uses species abundance and frequency in samples of pre-defined groups to judge the ability of each species to discriminate among pre-defined groups. An indicator value for each species is a percentage calculated by multiplying the following: 1) specificity (i.e. average occurrence of a species within a particular group divided by the average occurrence of the species in all groups); 2) fidelity (i.e. number of samples within a group in which a species occurs divided by the total number of samples within that group); and 3) 100 (Dufrêne and Legendre 1997). Each species was evaluated for its ability to discriminate among the two geologic substrates and three topographic positions. Species with significantly high indicator values define the groups. Since topographic position has more than two groups, one group was excluded (three two-group analyses were produced) to elucidate which group or groups were responsible for a significant indicator value (McCune and Mefford 1997). A Monte Carlo test evaluated the significance of each species to indicate each group. I accepted a *p* value of below 0.01.

Ward's method

Ward's minimum variance method is a hierarchical, polythetic agglomerative technique used to successfully reveal relationships among samples based on species (Gauch 1982). During each cycle of the classification, this method combines two samples or groups of samples whose fusion yields the lowest increase in within-group dispersion, minimizing the error sum of squares (or variance) (Clifford and Stephenson 1975, Kent and Coker 1992). The output is a dendrogram representing the relationship among the samples. I used the modified Braun-Blanquet values (see Table 5) for the species composition data in the analysis.

Twinspan

Twinspan is a polythetic, divisive classification (Gauch and Whittaker 1981) that has been extensively applied to vegetation data (Kent and Coker 1992). During each cycle of the classification, samples are divided into groups based on all the species information. A dichotomy is made by placing each sample on either a positive or negative side of a single ordination axis based on sets of differential species. A progressive division of samples forms a hierarchy of nested groups (Kent and Coker 1992). This classification of samples along a single axis then is used to ordinate a classification of species that characterize each group (Hill 1979). The sample and species classifications are represented in an ordered two-way table that displays the subdivisions of the data set.

Twinspan creates a variable called pseudospecies, which represents relative abundance levels of each species, and pseudospecies cut levels that define the range of the abundance levels. I chose modified Braun-Blanquet values (see Table 5) for the cut levels. Twinspan calculates indicator values for all pseudospecies, and it classifies groups of samples by species with the highest indicator values. I specified the maximum number of indicators per divisions as 7, the maximum level of divisions as 5, the minimum group size for divisions as 7, and the maximum number of species in the final table as 100.

Bray-Curtis ordination

Bray-Curtis ordination summarizes vegetation patterning by graphically displaying the similarity among samples based on species composition (Gauch 1982). I chose Bray-Curtis ordination because of its strong performance in analysis of ecological data when compared to other methods. It has been predictably useful for analysis of vegetation data (Beals 1984).

An ordination of vegetation samples finds the main axes of floristic variation that run through the dataset with a minimum of distortion and loss of information. With the assumption that floristic data inevitably reflects environmental variation, environmental data are evaluated indirectly as a second step (Bray and Curtis 1957, Kent and Coker 1992). Spearman's rank correlation coefficients show linear trends between an axis and either species or environmental gradients. If any significant correlations of an environmental variable and an axis result, environmental factors may be influencing floristic pattern (Kent and Coker 1992).

I specified the Sørenson distance measure [1-2W/(A+B)] and the variance-regression endpoint selection method (Beals 1984). I set the axis projection geometry and residual distances to Euclidean (Bray and Curtis 1957). I standardized the species composition datasets using the arcsine square root transformation on the proportional cover values of species (Sokal and Rohlf 1981).

Vegetation type descriptions with indicator species

Characteristic, or indicator, species are used to describe vegetation types (Kent and Coker 1992). Indicator species, as defined by Dufrêne and Legendre (1997), are "the most characteristic species of each group, found mostly in a single group of the typology and present in the majority of the sites belonging to that group." Dufrêne and Legendre (1997) criticized Twinspan's method of identifying indicator species and created a new algorithm for calculating indicator values of indicator species. Further, their method provides a criterion *a posteriori* to stop the subdivision process of a classification analysis, as indicator values are low if groups are either too finely or too coarsely divided (McCune and Mefford 1997).

I used a group's indicator species to characterize the clusters of samples recognized in Ward's method and Twinspan (see descriptions). I named major and minor groups, or vegetation types and subtypes, by the one to three dominant overstory species that have significantly high indicator values ($p < 0.01$) in the group. I recognized groups that had at least three replicate samples (Gauch 1982). Additional indicator species are listed for the vegetation types and subtypes. The species listed have their highest and statistically significant ($p < 0.01$) indicator values at that particular level of the hierarchy. Along with indicator species, common associates are listed in the vegetation type descriptions, which are species that have constancy greater than 0.5 but are not indicator species at that level of the hierarchy.

For vegetation type descriptions, I use the terminology of Sawyer and Keeler-Wolf (1995) where a dominant species is "an abundant species with high crown cover, especially in relation to other species in the stand". Important species are "two or more species with similar abundance and crown cover in relation to other species in the stand". Characteristic species have a high affinity to a vegetation type but may not dominate in the uppermost layer (The Nature Conservancy 1999).

I assigned the level of alliance to most vegetation types in the classification analyses, and the level of association to the finer subtypes. Following the conventions of The Nature Conservancy (1999), an alliance is a physiognomically uniform group of plant associations sharing one or more dominant or characteristic species that are found in the uppermost strata of the vegetation. An alliance is at the same level as "series" of Sawyer and Keeler-Wolf (1995). An association is a plant assemblage of definite floristic composition, uniform habitat conditions, and uniform physiognomy, which is the basic unit for vegetation classification (The Nature Conservancy 1999).

RESULTS

Direct analyses of the complete datasets

Descriptive statistics

I identified 245 species of vascular plant species (Appendix A) in eight sites where I located 262 samples of vegetation. Total richness was similar in granitic and calcareous water courses (Table 7). Mean richness was similar in canyons of both substrates and aspects. Further, richness was greatest in canyons than in the lower topographic positions. Mean richness was greater in six (of the eight) arroyos as compared to washes. Richness was greater, though, on limestone than on granite in both arroyos and washes. The calcareous Pachalka water course, with southwest to northeast aspects, was the richest at every topographic position.

Inspection of species percent cover revealed parallel relationships (Table 8). Cover was highest in canyons for all height classes, except for the tree layer on granite. Cover was slightly greater in arroyos as compared to washes. The ground layer was generally higher, though, on limestone than on granite in arroyos and washes.

All water courses were highly variable in elevation and slope (Table 9). The slope in the canyon sections was a factor of two to three times greater than the arroyo and wash sections, and each canyon spanned a greater elevation range than the lower positions. The slopes were similar across arroyos and washes, with the lowest slopes occurring in washes. The highest elevations overall occurred in three calcareous canyons.

Surface rock and sediment composition was variable and related to topographic position (Table 10). Rocks were significantly larger in canyons regardless of substrate.

Table 7. Total and mean number (± 1 S.D.) of vascular species per 0.1 ha in the eight water courses on granite and limestone in the complete dataset. Number of samples is denoted by n.

	Total richness		Mean richness		
Stand	Per water course	Per sample	Per canyon sample	Per arroyo sample	Per wash sample
A. All water courses	n=262	n=262	n=78	n=94	n=90
8 water courses	245	26.08(±10.19)	36.06(±6.32)	22.98(±8.86)	20.57(±7.51)
B. Granite	n=136	n=136	n=45	n=46	n=45
All granite	192	22.65(±10.46)	35.71(±5.34)	16.39(±5.53)	16.00(±3.88)
Budweiser	104	19.97(±10.33)	35.00(±5.81)	13.92(±2.81)	14.00(±2.52)
Willow Spring	114	22.02(±12.79)	40.25(±3.67)	13.71(±3.20)	14.30(±4.00)
Winston Basin	117	23.72(±8.81)	35.10(±2.92)	19.38(±5.66)	18.07(±4.03)
New York Peak	114	25.47(±8.50)	32.54(±5.32)	23.12(±6.08)	17.33(±3.28)
C. Limestone	n=126	n=126	n=33	n=48	n=45
All limestone	187	29.87(±8.44)	36.74(±7.42)	29.32(±6.63)	25.20(±7.44)
Mitchell Peak	111	25.71(±9.30)	35.44(±10.24)	24.20±(3.00)	16.43(±4.86)
Gilroy Canyon	129	27.84(±8.14)	38.25(±7.98)	27.72±(2.83)	21.54(±3.48)
Pachalka Spring	110	36.63(±4.90)	39.28(±5.22)	38.90±(2.47)	33.46(±4.54)
Clark Mountain	114	29.27(±7.06)	35.11(±6.19)	29.08±(6.18)	25.08(±5.63)

Table 8. Mean species percent cover (± 1 S.D.) per 0.1 ha in the water courses on granite and limestone in the complete dataset. Number of samples is denoted by n.

Sample characteristic	Per sample	Per canyon sample	Per arroyo sample	Per wash sample
A. Granite	n=136	n=45	n=46	n=45
All vegetation layers	18.84(±11.32)	26.93(±14.60)	17.92(±7.85)	12.63(±3.42)
Tree	2.04(±3.61)	2.91(±4.45)	3.17(±4.02)	0.49(±1.26)
Shrub	15.69(±9.10)	21.43(±12.20)	14.60(±6.73)	11.59(±3.23)
Ground	2.18(±2.55)	4.41(±3.25)	1.09(±1.06)	1.06(±0.83)
Non-native	2.09(±2.42)	3.41(±3.19)	1.70(±1.79)	1.24(±1.38)
B. Limestone	n=128	n=33	n=48	n=45
All vegetation layers	19.55(±8.17)	27.77(±8.33)	18.10(±6.44)	15.11(±4.70)
Tree	3.32(±5.27)	6.61(±7.54)	3.00(±4.37)	1.52(±2.40)
Shrub	14.04(±5.24)	18.86(±4.97)	12.70(±4.54)	11.75(±3.81)
Ground	3.22(±2.18)	3.76(±2.98)	3.77(±2.04)	2.40(±1.29)
Non-native	1.55(±1.72)	2.07(±2.04)	1.53(±1.73)	1.17(±1.44)

Table 9. Elevation range and mean percent slope (± 1 S.D.) per 0.1 ha in the eight water courses on granite and limestone in the complete dataset. Number of samples is denoted by n.

	Elevation range in meters			Mean percent slope		
Water courses	Per canyon sample	Per arroyo sample	Per wash sample	Per canyon sample	Per arroyo sample	Per wash sample
A. Granite	n=45	n=46	n=45	n=45	n=46	n=45
All granite	1170–1705	953–1230	840–1135	11.7(±6.6)	4.0(±0.8)	2.9(±0.8)
Budweiser	1174–1670	971–1158	875–953	14.0(±8.4)	3.8(±0.6)	3.0(±0.4)
Willow Spring	1110–1610	953–1126	840–932	9.4(±4.0)	3.9(±0.7)	2.3(±1.1)
Winston Basin	1250–1705	1105–1230	864–1080	12.8(±9.0)	5.2(±0.6)	3.1(±0.9)
New York Peak	1225–1655	1145–1210	1040–1135	11.0(±4.0)	3.3(±0.4)	3.1(±0.4)
B. Limestone	n=33	n=48	n=45	n=33	n=48	n=45
All limestone	1165–1830	845–1488	730–1330	11.7(±6.5)	5.0(±1.3)	3.3(±0.8)
Mitchell Peak	1165–1530	845–1130	730–835	12.6(±6.5)	4.8(±1.3)	3.6(±0.5)
Gilroy Canyon	1328–1728	1063–1293	980–1060	15.1(±9.8)	5.0(±1.9)	2.5(±0.4)
Pachalka Spring	1503–1741	1279–1447	1053–1238	10.9(±5.6)	5.4(±0.9)	3.9(±0.6)
Clark Mountain	1508–1830	1346–1488	1150–1330	8.3(±1.8)	4.7(±0.9)	3.4(±0.8)

Table 10. Mean percent cover of rock and sediment (± 1 S.D.) per 0.1 ha in the water courses on granite and limestone in complete dataset. Number of samples is denoted by n. Small rock (<2.5 cm) is fine and gravel combined, and large rock (>2.5 cm) is the percent cobble, stone, boulder, and bedrock combined.

Sample characteristic	Per sample	Per canyon sample	Per arroyo sample	Per wash sample
A. 8 water courses	n=262	n=78	n=94	n=90
Fine %	14.26(±14.67)	7.85(±7.98)*	15.30(±17.51)*	18.74(±14.08)*
Gravel %	51.46(±17.84)	33.18(±18.09)*	17.33(±13.61)	60.75(±9.36)
Cobble %	15.86(±13.34)	16.74(±14.84)*	45.34(±14.87)*	13.89(±11.68)*
Stone %	5.22(±4.05)	7.76(±4.94)*	14.15(±4.45)*	3.70(±2.84)*
Boulder %	6.74(±11.04)	17.89(±14.46)*	3.69(±2.89)*	1.30(±1.56)
Bedrock %	3.67(±9.66)	11.28(±14.47)*	0.28(±1.67)	0.38(±3.17)
Small rock%	65.73(±24.05)	41.89(±19.16)	72.17(±20.45)*	79.50(±14.60)*
Large rock%	31.50(±22.59)	52.73(±17.89)	24.74(±20.16)*	19.26(±14.58)*
Litter %	2.34(±3.00)	4.32(±4.50)	1.62(±1.19)	1.56(±0.89)
B. Granite	n=136	n=45	n=46	n=45
Fine %	22.59(±14.94)	12.47(±7.55)+w	27.50(±17.78)	27.69(±12.15)
Gravel %	50.51(±20.54)	28.24(±14.40)+w	60.89(±15.17)	62.16(±9.66)
Cobble %	5.75(±3.83)	6.53(±3.35)	5.54(±5.11)	5.18(±2.69)
Stone %	3.31(±3.60)	6.28(±3.42)+w	1.79(±3.19)	1.90(±2.07)
Boulder %	8.42(±13.38)	22.73(±14.94)+w	1.71(±3.28)	0.97(±1.33)
Bedrock %	6.16(±12.44)	17.80(±15.71)+w	0.16(±0.73)	0.66(±4.47)
Small rock %	71.52(±28.41)	40.71(±19.37)+w	88.38(±12.40)	89.84(±6.18)
Large rock %	23.13(±24.55)	53.35(±18.38)+w	9.20(±11.20)	8.71(±6.17)
Litter %	2.68(±3.14)	4.52(±4.52)w	2.22(±1.87)	1.31(±0.75)
C. Limestone	n=126	n=33	n=48	n=45
Fine %	5.27(±7.17)	1.54(±1.97)w	3.60(±4.28)a	9.79(±9.45)
Gravel %	52.53(±14.38)	41.97(±18.42)+w	53.40(±10.95)	59.36(±8.95)
Cobble %	26.82(±11.13)	27.91(±10.98)	30.04(±10.62)a	22.60(±10.65)
Stone %	7.29(±3.50)	8.94(±4.01)w	7.85(±3.33)a	5.49(±2.34)
Boulder %	4.93(±7.41)	11.97(±11.50)+w	3.20(±2.27)a	1.62(±1.72)
Bedrock %	0.98(±3.71)	3.07(±6.35)+w	0.38(±2.18)	0.09(±0.47)
Small rock %	56.53(±19.21)	42.91(±18.67)+w	57.52(±13.34)a	69.15(±13.20)
Large rock %	39.63(±17.19)	52.01(±16.96)+w	41.00(±13.45)a	29.80(±12.81)
Litter %	1.98(±2.82)	4.02(±4.64)+w	1.42(±1.24)	1.07(±1.00)

A two sample *t*-test showed significant differences ($p<0.01$) for the following:
* between the granite and limestone water courses.
\+ between canyon and arroyo groups of granitic or calcareous water courses.
w between canyon and wash groups of granitic or calcareous water courses.
a between arroyo and wash groups of granitic or calcareous water courses.

Among all canyons, granite had significantly more fine sediment, boulder, and bedrock while limestone had significantly more gravel, cobble, and stone. The size and percent cover of rocks were similar among arroyos and washes of the same substrate, in which smaller rocks (especially fine sediment) were significantly greater on granite while larger rocks (especially cobbles and stones) were significantly greater on limestone.

Multi-response permutation procedures (MRPP) of substrate and position

I used 112 of the 245 vascular plant species (Appendix B) and 258 of the 262 samples (Appendix D) for analyses of the complete dataset (after eliminating rare species and outlier samples). The MRPP for geologic substrate was significant (Test statistic: T = -53.970003 and $p < 0.00000$). Therefore, I rejected the null hypothesis that substrate has no effect on species composition. The MRPP for topographic position generated significant p-values ($p<0.00000$) for all analyses (Table 11). Thus, I rejected the null hypothesis that topographic position has no effect on species composition. In the two group analyses, the canyon and wash positions had the most separation.

Indicator Species analyses of substrate and position

When considering geologic substrate in the complete dataset, the limestone group had the highest number of significant indicator species ($p<0.01$) with 48 vascular plants (Table 12). Further, the indicator species for limestone had higher indicator values than for granite. Of this group, 14 were restricted to limestone (with indicator values for granite = 0), and 32 preferred limestone (indicator values for granite > 0). Another seven

Table 11. Multi-response permutation procedures for topographic position in the complete dataset ($p<0.0000$ for each analysis).

Topographic positions in analysis	Test statistic
Canyon, arroyo, and wash (258 samples by 114 species)	T = -92.051584
Canyon and wash (164 samples by 114 species)	T = -82.019531
Canyon and arroyo (168 samples by 114 species)	T = -56.393781
Arroyo and wash (184 samples by 101 species)	T = -18.275710

Table 12. Indicator species and values for geologic substrate in the complete dataset. Number of samples is denoted by n, and indicator value by IV. See Appendix A for complete scientific names (for the level of subspecies and variety).

A. Granite, n=132

Species	IV	Species	IV	Species	IV
1. only (p<0.01)		*Muhlenbergia rigens*	10	*Senecio flaccidus*	23
Ephedra californica	38	*Quercus turbinella*	10	*Brickellia californica*	17
Isomeris arborea	38	*Sonchus oleracea*	9	*Psorothamnus*	11
Eriogonum wrightii	15	*Tamarix ramosissima*	9	*arborescens*	
Opuntia ramosissima	15	*Bromus diandrus*	8	3. weakly prefer (p<0.05)	
Eriogonum plumatella	12	2. prefer (p<0.01)		Lichen	16
Pholisma arenaria	11	*Schismus barbatus*	53	*Senna armata*	14
Ericameria cuneata	10	*Hymenoclea salsola*	50	*Purshia tridentata*	8
Datura wrightii	10	*Baccharis sergiloides*	29		
Juncus macrophyllus	10	*Lotus rigidus*	27		

B. Limestone, n=136

Species	IV	Species	IV	Species	IV
4. only (p<0.01)		*Stephanomeria*	47	*Mirabilis pumila*	21
Opuntia phaeacantha	40	*pauciflora*		*Bebbia juncea*	20
Tridens muticus	37	*Salvia dorrii*	46	*Phoradendron*	20
Yucca breviflora	28	*Acacia greggii*	45	*californicum*	
Purshia mexicana	22	*Encelia virginensis*	44	*Krameria erecta*	18
Escobaria vivipara	21	*Sphaeralcea ambigua*	43	*Muhlenbergia porteri*	17
Gaura cocinnea	21	*Ephedra nevadensis*	39	*Chamaesyce*	16
Psilostrophe cooperi	21	*Thamnosma montana*	39	*albomarginata*	
Allionia incarnata	13	*Viguiera parishii*	35	*Physalis crassifolia*	15
Coleogyne ramossisma	13	*Oenothera caespitosa*	35	*Chrysothamnus*	14
Encelia farinosa	13	*Echinocereus*	34	*paniculatus*	
Brickellia multiflora	12	*engelmannii*		*Mirabilis multiflora*	14
Astragalus	10	*Gutierrezia sarothrae*	34	*Castilleja angustifolia*	9
lentiginosus		*Opuntia acanthocarpa*	33	*Tragia ramosa*	9
Eriogonum heermanii	10	*Yucca baccata*	33	6. weakly prefer (p<0.05)	
Hedeoma nana	10	*Ambrosia eriocentra*	31	*Mirabilis bigelovii*	25
5. prefer (p<0.01)		*Aristida purpurea*	30	*Opuntia basilaris*	14
Penstemon palmeri	70	*Salazaria mexicana*	29	*Galium angustifolium*	9
Bromus madritensis	50	*Chilopsis linearis*	28	*Castilleja linearifolia*	9
Erioneuron pulchellum	49	*Physalis hederifolia*	25	*Garrya flavescens*	6
Eriogonum inflatum	47	*Ephedra viridis*	23		

species weakly preferred ($p<0.05$) limestone. Many of these species, though, may occur off limestone in other parts of their range (e.g. *Yucca breviflora, Coleogyne ramosissima, Bromus madritensis, Sphaeralcea ambigua, Mirabilis bigelovii* etc.). The granite group had 21 indicators ($p<0.01$). Of this group, 14 were restricted to granite, and seven preferred granite. Another two species weakly preferred ($p<0.05$) granite. Species with high indicator values (in order from highest to lower value) for limestone were *Penstemon palmeri, Bromus madritensis*, and *Erioneuron pulchellum* while for granite they were *Schismus barbatus, Hymenoclea salsola*, and *Ephedra californica.* Another 45 species not listed in Table 12 were partial to neither granite nor limestone.

When considering topographic position, the highest number of indicators occurred with the canyon group, which was significantly different from the arroyo and wash groups. In particular, 43 out of the 112 vascular species had significant *p*-values ($p<0.01$) in the canyon and arroyo analysis and the canyon and wash analysis, but non-significant *p*-values for the arroyo and wash analysis (Sections A and I in Table 13 and in Appendix E). Thus, many species were associated with canyons situated in mountains or with the arroyos and washes beyond the mountains. Thirty-two of these 43 species had significantly high indicator values for canyon group and were rarely if at all found in the arroyo and wash groups (Section A). These included *Elymus elymoides, Pinus monophylla,* and *Baccharis sergiloides.* The 11 remaining species had significantly high indicator values in the arroyo and wash groups and were rarely if at all found in the canyon group (Section I). These include *Erodium cicutarium, Encelia virginensis, Eriogonum inflatum*, and *Ambrosia eriocentra.*

Table 13. Indicator species and values for topographic groups in the complete dataset. Refer to Appendix E for specific species in each section. Codes in table are as follows C=canyon, A=Arroyo, W=wash.

Topographic group in which species are associated	Number of species
A. C only, not A and W	32
B. C, decreases in A and then W	14
C. C and A, not W	5
D. C, not W	5
E. Indifferent to topographic position	21
F. W, not C	9
G. W, not A and C	1
H. W, decreases in A and then C	6
I. A and W, not C	11
J. Other	9

Another 20 species had significant differences in all three two-group analyses (Sections B and H in Table 13 and Appendix E). Fourteen of these 20 species had indicator values that were significantly highest for the canyon group, and then decreased in the arroyo to wash groups (Section B). These include *Artemisia ludoviciana, Rhus trilobata, Ericameria linearifolia, Prunus fasciculata,* and *Yucca baccata.* On the other hand, six species had values highest for the wash group and decreased in arroyo to canyon groups (Section H), including *Hymenoclea salsola, Larrea tridentata, Chrysothamnus paniculatus,* and *Ambrosia dumosa.*

Other topographic patterns include six species that had significant differences in the canyon and wash analysis and the arroyo and wash analysis (Sections C and G in Table 13 and Appendix E); thus, these species were associated with the canyon and arroyo groups. Fourteen species had significant values for the canyon and wash analysis only (Sections D and H); thus, they discriminated on a disjunct topographic group, canyon or wash, but not on the overlapping groups. An additional 21 species did not discriminate on any particular topographic position (Section E). Lastly, nine species displayed various other patterns (Section J).

Classification and ordination of the complete datasets

I produced initial cluster analyses and ordination based on species composition. All analyses generated two distinct groups: one of canyon samples and another of wash and arroyo samples. For example, the ordination (Figure 5) displays a clear break between canyon samples and arroyo/wash samples, with 38.6% and 27.1% of the

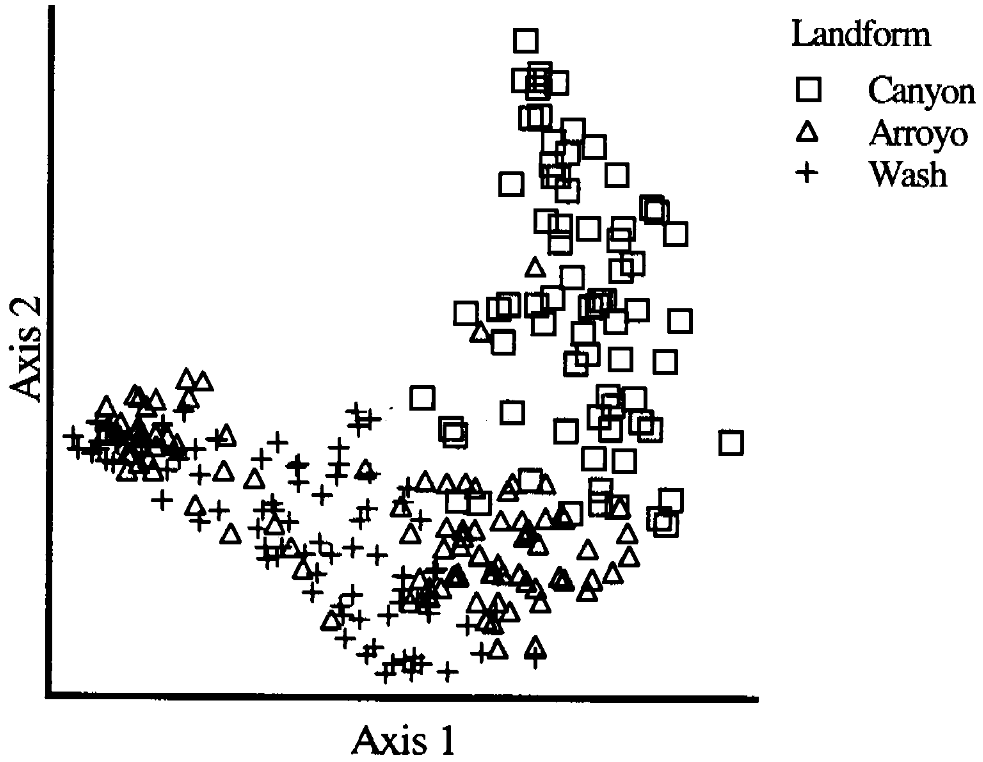

Figure 5. Bray-Curtis diagram of 258 vegetation samples in the complete dataset based on topographic position.

variation explained in the first and second axis, respectively. Also in Figure 5, the two separate distributions of arroyo samples are correlated with geologic substrate: The granitic arroyos are primarily along the left side of axis 1 and calcareous arroyos along the right side of axis 1. Further, the classification analyses also sharply separated canyon samples from arroyo and wash samples, with their outputs described: The Ward's method produced discrete canyon groups (one granitic group and one calcareous group) at the five-cluster level. Twinspan sharply separated canyon samples from arroyo and wash samples; in the first division, the canyon samples were separated as a group from most of the arroyo samples and all of wash samples.

The distinct groupings in the ordination and classification analyses occurred when cover of each species was separated into the three vertical height classes (i.e. ground, shrub, and tree categories) as well as when cover was combined. Because of the distinct separation in all analyses, I analyzed the canyon samples separately from arroyo and wash samples, and I combined the vertical height classes in the species composition datasets.

Classification of the canyon dataset

I used 156 out of the 250 vascular plant species (Appendix B) and 74 out of the 78 samples (Appendix D) for the canyon analyses (after eliminating rare species and outlier samples). The vegetation pattern is best interpreted by the Ward's method (Figure 6). The hierarchical classification of Twinspan was similar to Ward's method (see Appendix F for Twinspan table) so the specific divisions are not discussed at detail.

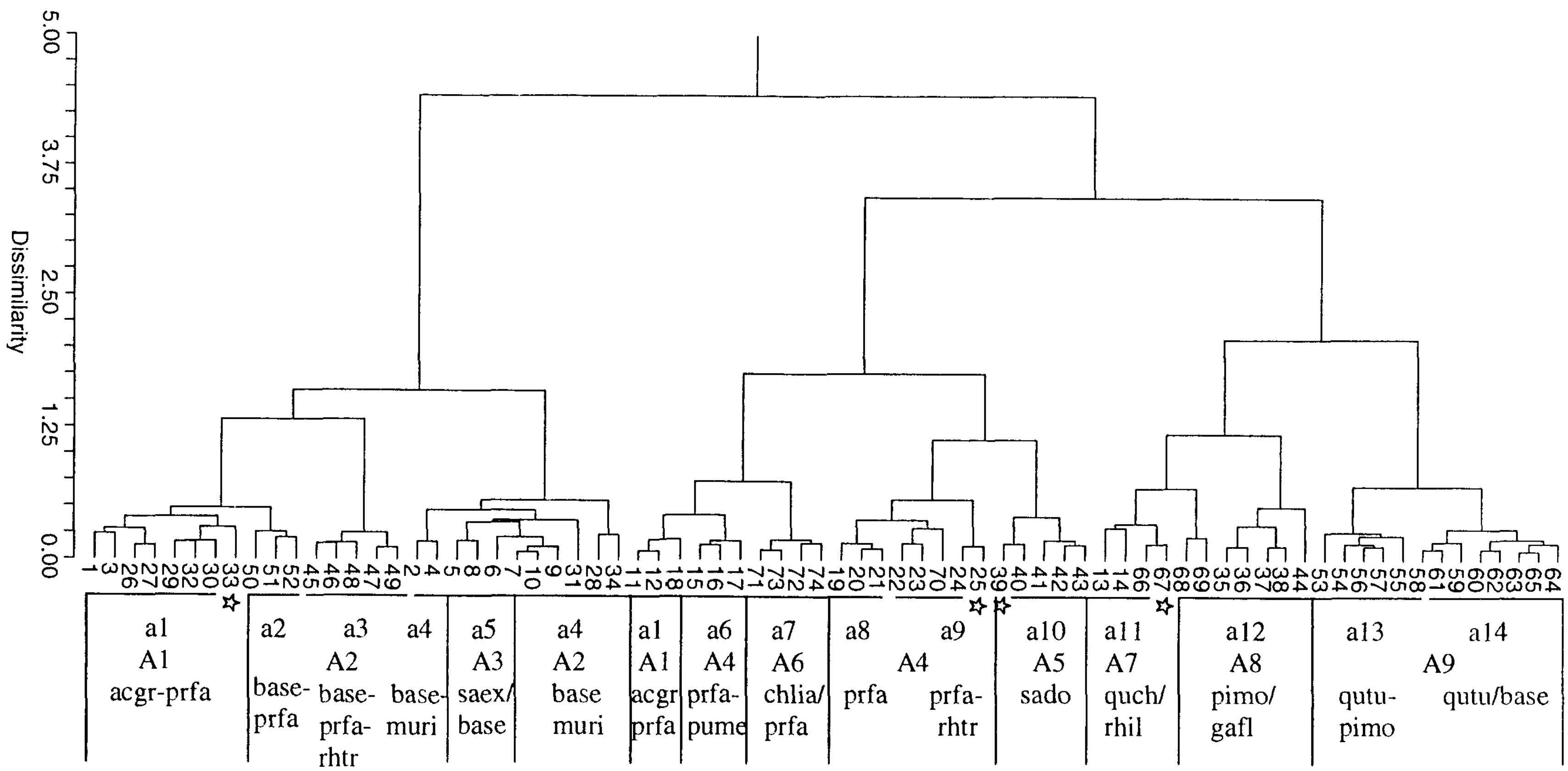

Figure 6. Ward's dendrogram for the 74 canyon samples. Sample locations are in Appendix D. Group names are abbreviated as A=alliance and a=association. They correspond to A1. *Acacia greggii* alliance, a1. *Acacia greggii-Prunus fasciculata* association, A2. *Baccharis sergiloides* alliance, a2. *Baccharis sergiloides-Prunus fasciculatata* association, a3. *Baccharis sergiloides-Prunus fasciculata-Rhus trilobata* association, a4. *Baccharis sergiloides/Muhlenbergia rigens*, A3. *Salix exigua alliance*, a5. *Salix exigua/Baccharis sergiloides* association, A4. *Prunus fasciculata* alliance, a6. *Prunus fasciculata-Purshia mexicana* association, a8. *Prunus fasciculata* undifferentiated, a9. *Prunus fasciculata-Rhus trilobata* association, A5. *Salvia dorrii* alliance, a10. *Salvia dorrii* undifferentiated, A6. *Chilopsis linearis* alliance, a7. *Chilopsis linearis/Prunus fasciculata* association, A7. *Quercus chrysolepis* alliance, a11. *Quercus chrysolepis/Rhamnus ilicifolia* association, A8. *Pinus monophylla* alliance, a12. *Pinus monophylla/Garrya flavescens* association, A9. *Quercus turbinella* alliance, a13. *Quercus turbinella-Pinus monophylla* association, a14. *Quercus turbinella/Baccharis sergiloides* association. The plots with a ✡ are unrecognized *Pinus monophylla* associations.

Further, the results of the ordination are comparable to the classificatory methods (Figures 7 and 8), where Ward's method demonstrates a tighter clustering of group 2.

Both classifications generated the following main vegetation types: 1) *Acacia greggii* dominant with *Prunus fasciculata;* 2) *Baccharis sergiloides* dominant with *Muhlenbergia rigens* or *Prunus fasciculata;* 3) *Chilopsis linearis* dominant with *Viguiera parishii* and *Prunus fasciculata*; 4) *Prunus fasciculata* dominant with various associates; 5) *Salvia dorrii;* 6) *Quercus chrysolepis* dominant with *Rhamnus ilicifolia;* 7) *Pinus monophylla* dominant with *Garrya flavescens;* 8) *Quercus turbinella* dominant with *Pinus monophylla* or *Baccharis sergiloides.*

For canyon vegetation, I recognize eight main types as alliances based on dominant or characteristic overstory species and 14 total subtypes as associations based on dominant or important understory species (Figure 6). Alliances form distinct clusters in the ordination diagram (Figure 9) with respect to the types from the Ward's dendrogram (Figure 6). The associations are generally distinct (Figure 10). Although I only sampled four *Salix exigua* stands (three samples allied with the *Baccharis* type and one outlier sample) and one *Populus fremontii* stand (an outlier sample), I consider them as distinct stands of alliances that are extensive in more mesic areas of California (Sawyer and Keeler-Wolf 1995).

I found *Pinus monophylla,* normally an upland species, as the dominant species in some upper canyon samples. The samples are starred in the Ward's dendrogram, which occur in four clusters (Figure 6). The pine associates with *Rhamnus ilicifolia* and *Rhamnus tomentella* in upper Gilroy canyon, with *Prunus fasciculata* in uppermost

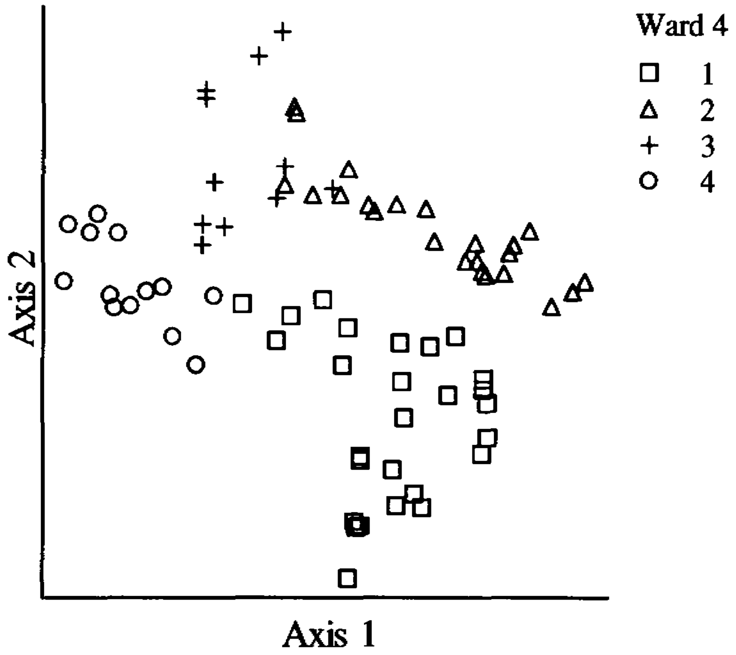

Figure 7. Ordination diagram of Ward's method groups at the four-cluster level in the canyon dataset.

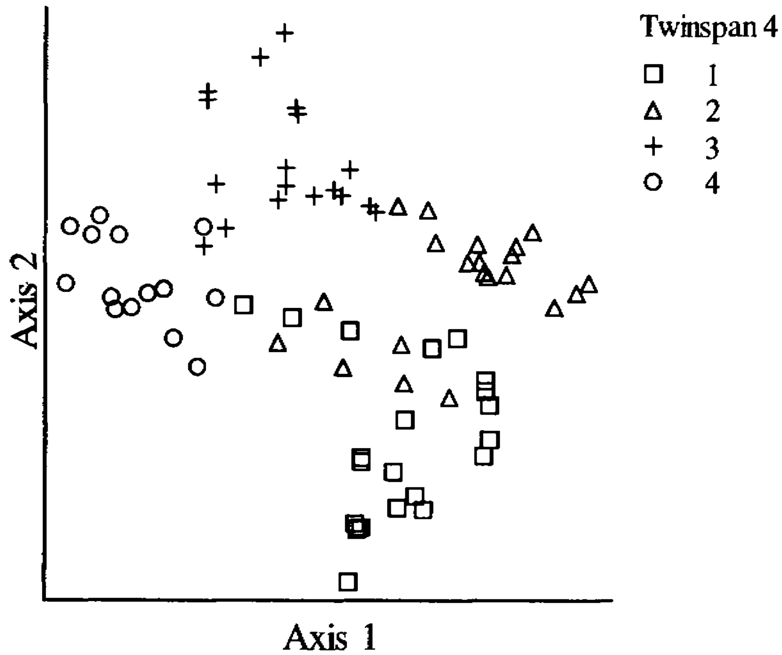

Figure 8. Ordination diagram of Twinspan groups at the four-cluster level in the canyon dataset.

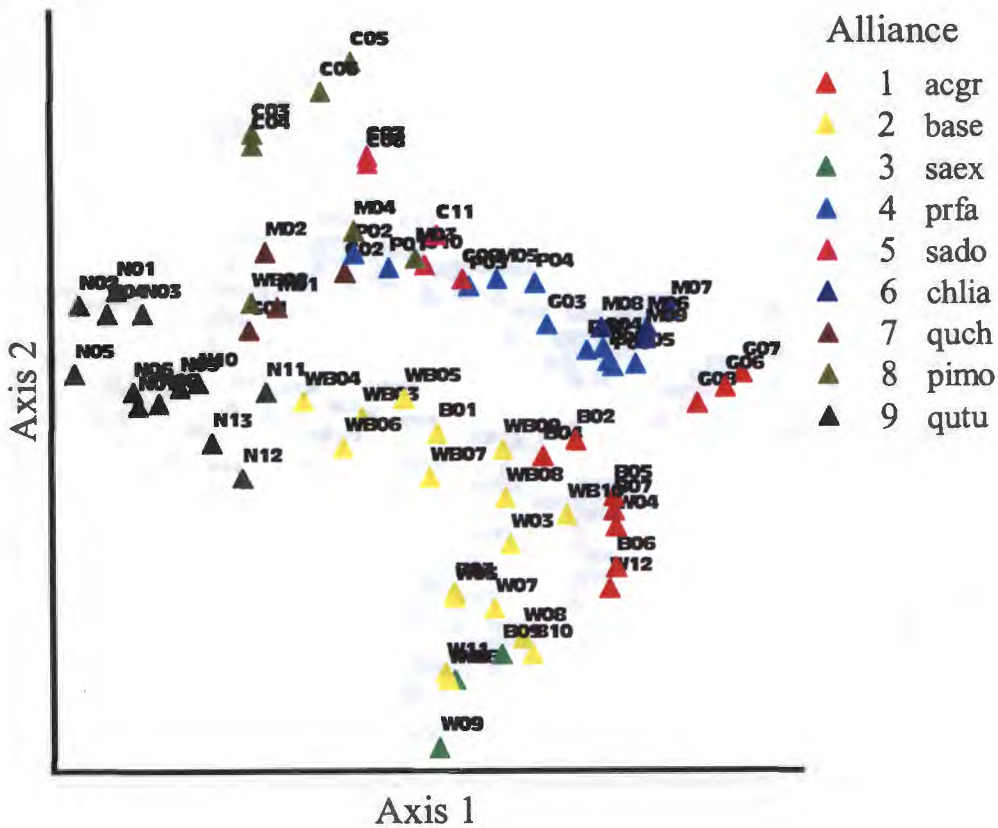

Figure 9. Bray-Curtis ordination diagram for alliances of 74 canyon plots of the eastern Mojave Desert. In legend, alliance numbers correspond to codes in Figure 6 and vegetation descriptions, and species codes correspond to codes in Appendix B.

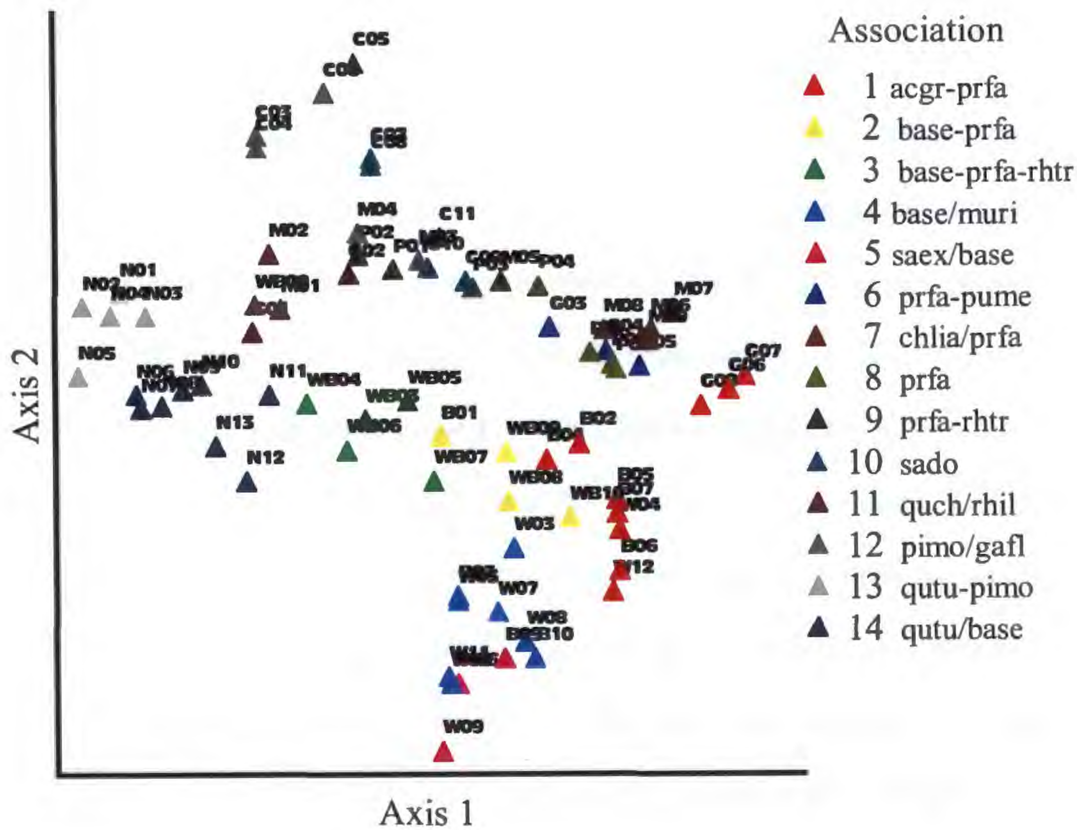

Figure 10. Bray-Curtis ordination diagram for associations of 74 canyon plots of the eastern Mojave Desert. In legend, association numbers correspond to codes in Figure 6 and vegetation descriptions, and species codes correspond to codes in Appendix B.

Pachalka canyon, with *Baccharis sergiloides* in uppermost Budweiser canyon, and with *Prunus fasciculata* and *Salvia dorrii* in middle Clark Canyon. These are viewed as a component of the *Pinus monophylla* woodland alliance, but they are not recognized as associations because of limited data.

Classification of the arroyo/wash dataset

I used 89 out of the 156 plants (Appendix B) and 181 out of 186 samples (Appendix D) for the arroyo/wash analyses (after eliminating rare species and outlier samples). The vegetation pattern is best interpreted by the Ward's method (Figure 11). Twinspan (Appendix G) clustered the samples in similar groups as Ward's method; thus, the specific divisions are not discussed at detail. Further, the results of the ordination are comparable to the classificatory methods at the four-cluster level (Figures 12 and 13).

Both classification methods generated the following main types: 1) *Acacia greggi* dominant with various understory associates; 2) *Encelia virginensis* dominant with *Salvia dorrii*; 3) *Chilopsis linearis* dominant with various understory associates; 4) *Prunus fasciculata* dominant with *Ambrosia eriocentra;* 5) *Chrysothamnus paniculatus* dominant; 6) *Hymenoclea salsola* dominant; 7) *Ephedra californica* dominant with *Hymenoclea salsola.* The sample clusters with *Acacia greggii* or *Chilopsis linearis* as the dominant overstory species are scattered in both classifications because these two species have similar understory plants associated with them depending on the site location. The understory associations in common for *Acacia* and *Chilopsis* are *Hymenoclea salsola, Salvia dorrii,* and *Viguiera parishii.* The circumscription of *Chilopsis* and *Acacia*

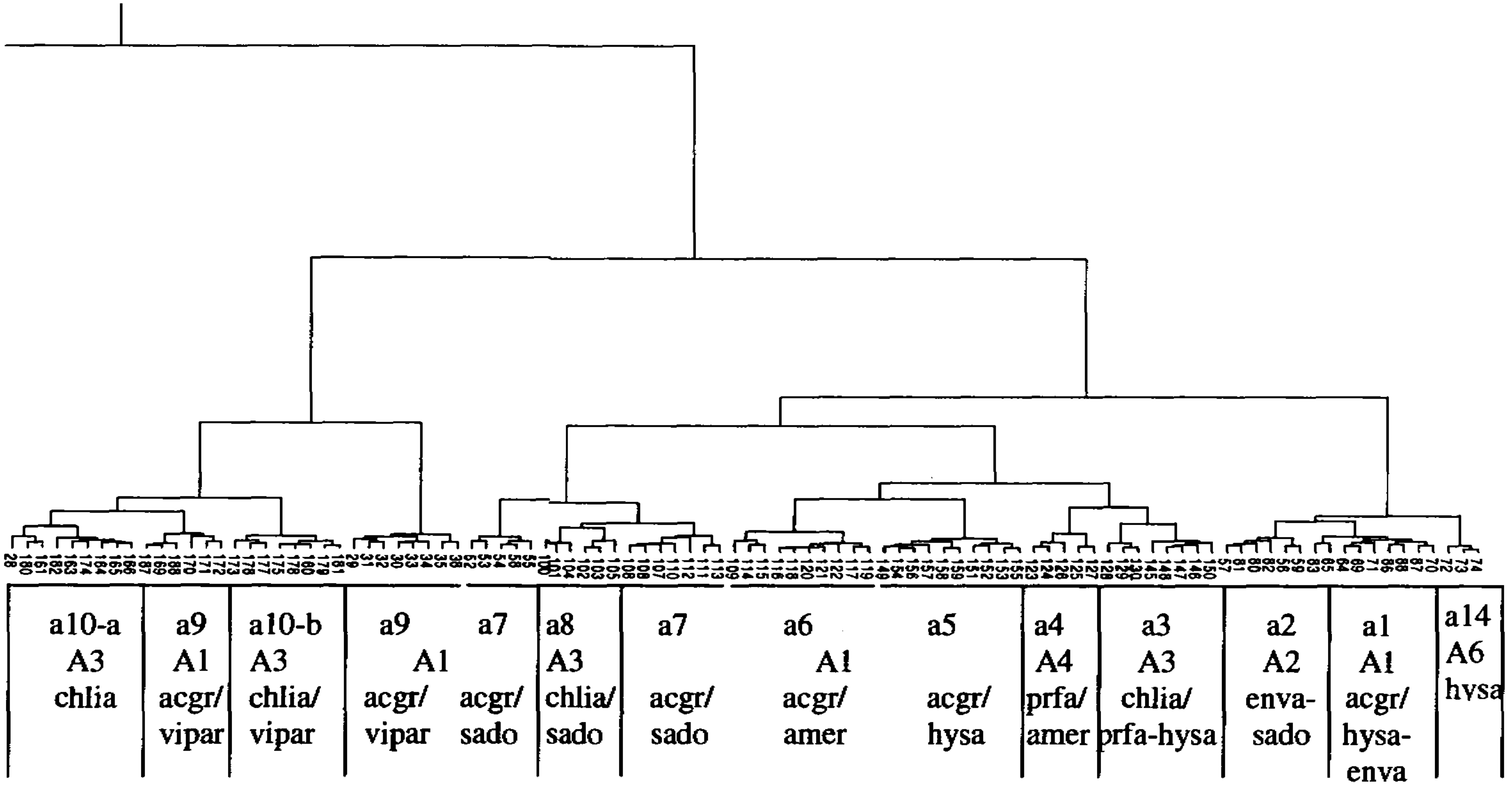

Figure 11. Ward's dendrogram for the 181 arroyo and wash samples. Sample locations are in Appendix D. Group names are abbreviated as A=alliance and a=association. They correspond to A1. *Acacia greggii* alliance, a1. *Acacia greggii/ Hymenoclea salsola-Encelia virginesis* association, a5. *Acacia greggi/Hymenoclea salsola* association, a6. *Acacia greggii/Ambrosia eriocentra* association, a7. *Acacia greggii/Salvia dorrii* association, a9. *Acacia greggii/Viguiera parishii* association; A2. *Encelia virginensis* alliance, a2. *Encelia virginensis-Salvia dorrii* association; A3. *Chilopsis linearis* alliance, a3. *Chilopsis linearis/Prunus fasciculata-Hymenoclea salsola* association, a8. *Chilopsis linearis/Salvia dorii* association, al0-a. *Chilopsis linearis,* al0-b. *Chilopsis linearis/ Viguiera parishii* associations, A4. *Prunus fasciculata* alliance, a4. *Prunus fasciculata/Ambrosia eriocentra* association.

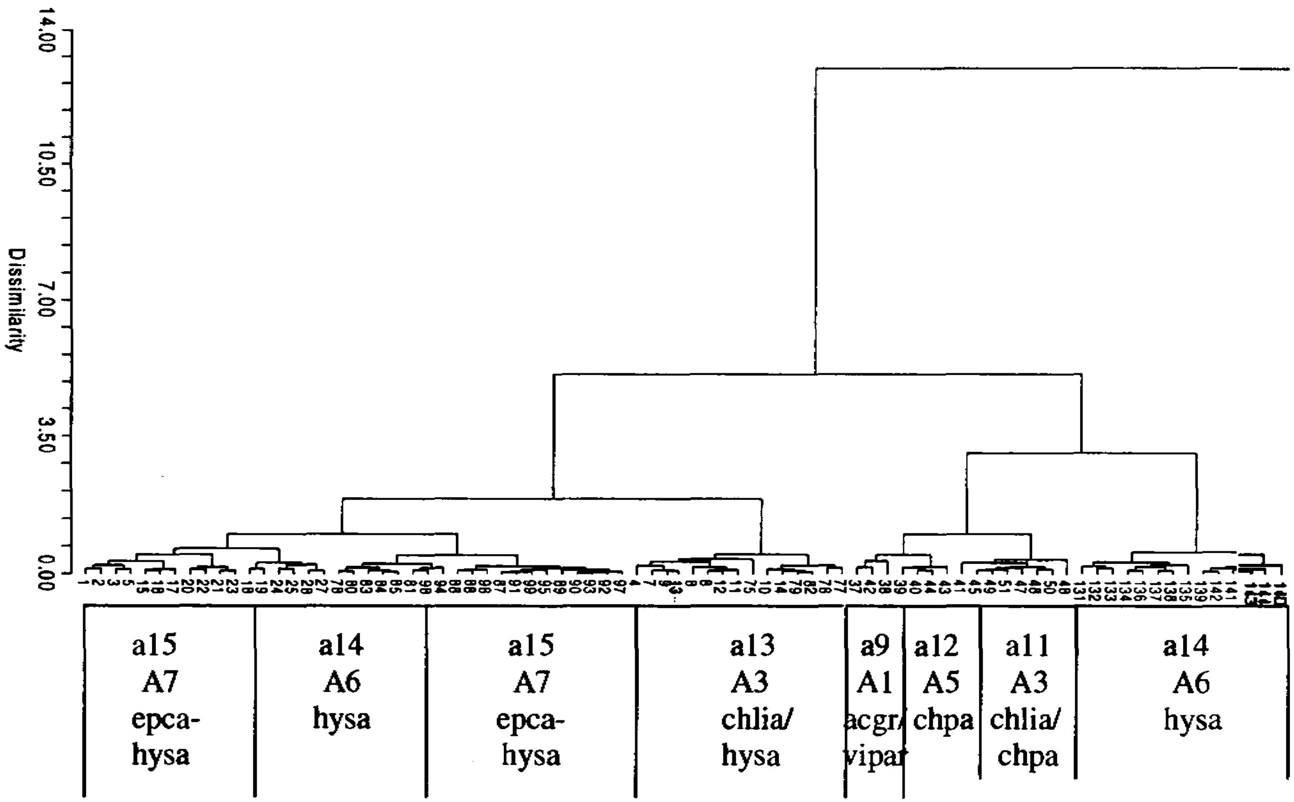

Figure 11. Continued. A1. *Acacia greggii* alliance, a9. *Acacia greggii/Viguiera parishii* association; A3. *Chilopsis linearis* alliance, a11. *Chilopsis linearis/Chrysothamnus paniculatus* association, a13. *Chilopsis linearis/Hymenoclea salsola* association; A5. *Chrysothamnus paniculatus* alliance, a12. *Chrysothamnus paniculatus* undifferentiated; A6. *Hymenoclea salsola* alliance, a14. *Hymenoclea salsola* undifferentiated; A7. *Ephedra californica* alliance, a15. *Ephedra californica/Hymenoclea salsola* association.

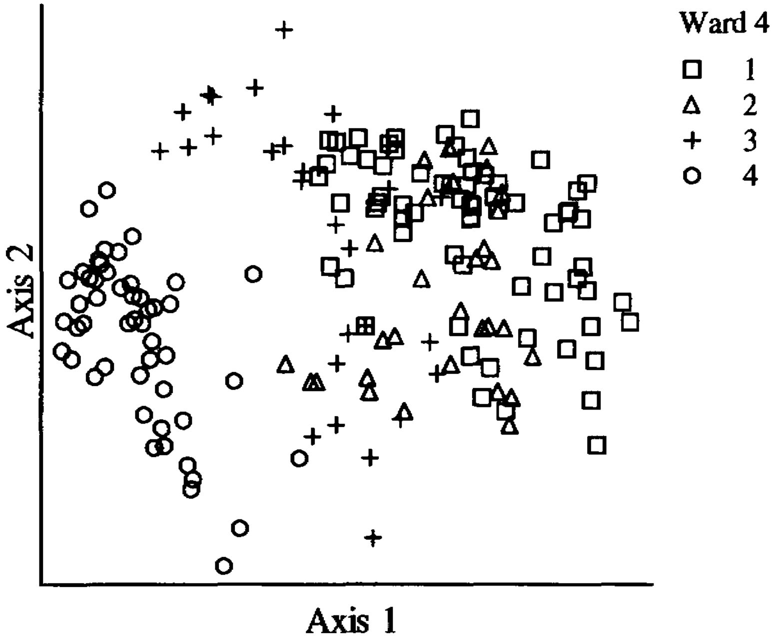

Figure 12. Ordination diagram of Ward's method groups at the four-cluster level in the arroyo/wash dataset.

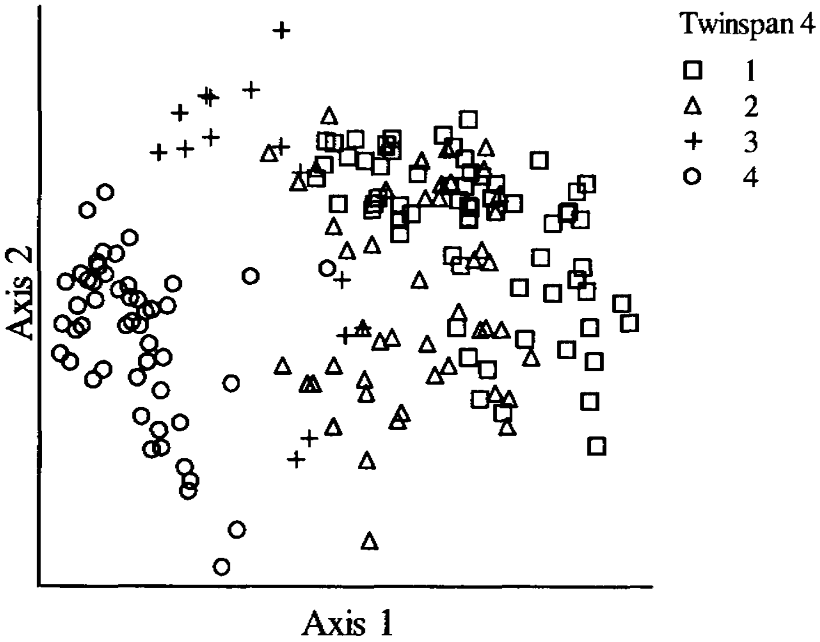

Figure 13. Ordination diagram of Twinspan groups at the four-cluster level in the arroyo/wash dataset.

subtypes are based on small clusters because they form clearly distinct subgroups in both the classifications and in the ordination.

For the arroyos and washes, I define seven main types based on the dominant or characteristic overstory species and 16 subtypes based on the dominant understory or important species. The alliances form distinct clusters in the ordination diagram (Figure 14). The associations in the ordination for the subtypes of Ward's dendrogram are less obvious than the canyon dataset yet still distinct (Figure 15). The only type that did not cluster very tightly was Alliance 4 with overstory *Prunus fasciculata* and understory *Ambrosia eriocentra* dominating this type. *Prunus* is mainly a canyon species (per Appendix E), but this type is at the mountain front where arroyo and wash species are common. I recognized the *Psorothamnus spinosus* alliance even though it was represented in two plots. This is a common alliance in other North American deserts, and is at its northern range limit in this part of the Mojave Desert (Spolsky 1979, Peinado et al. 1995, Keeler-Wolf et al. 1998, Thomas et al. 1999).

Bray-Curtis ordination of the canyon datasets

The first three axes of the Bray-Curtis ordination account for 72.8% of the variation in the species composition dataset (Table 14). Two interpretable axes were generated: The first axis accounted for 35% of the variation, and the second axis accounted for an additional 33.8%.

The ordination patterns of species in sample space support the classification of vegetation types and subtypes (Figure 9 and 10), as many species are strongly correlated ($r>0.5$) with the first and second axes (Table 15). The greatest separation along the first

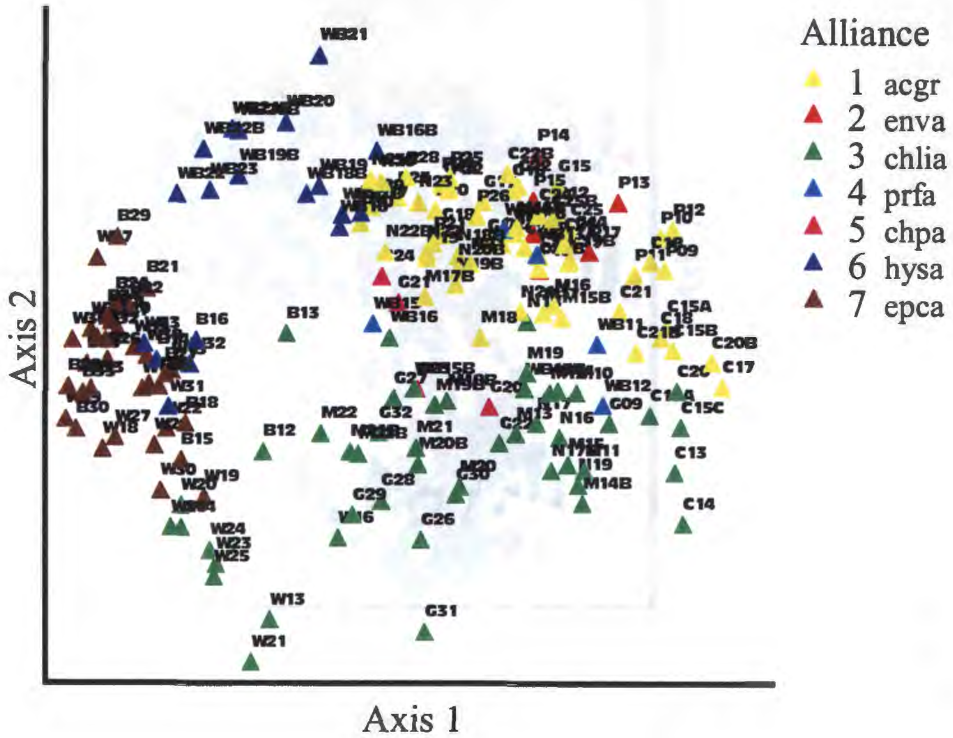

Figure 14. Bray-Curtis ordination diagram for alliances of 181 arroyos and washes of the eastern Mojave Desert. In legend, alliance numbers correspond to codes in Figure 11 and vegetation descriptions, and species codes correspond to codes in Appendix B.

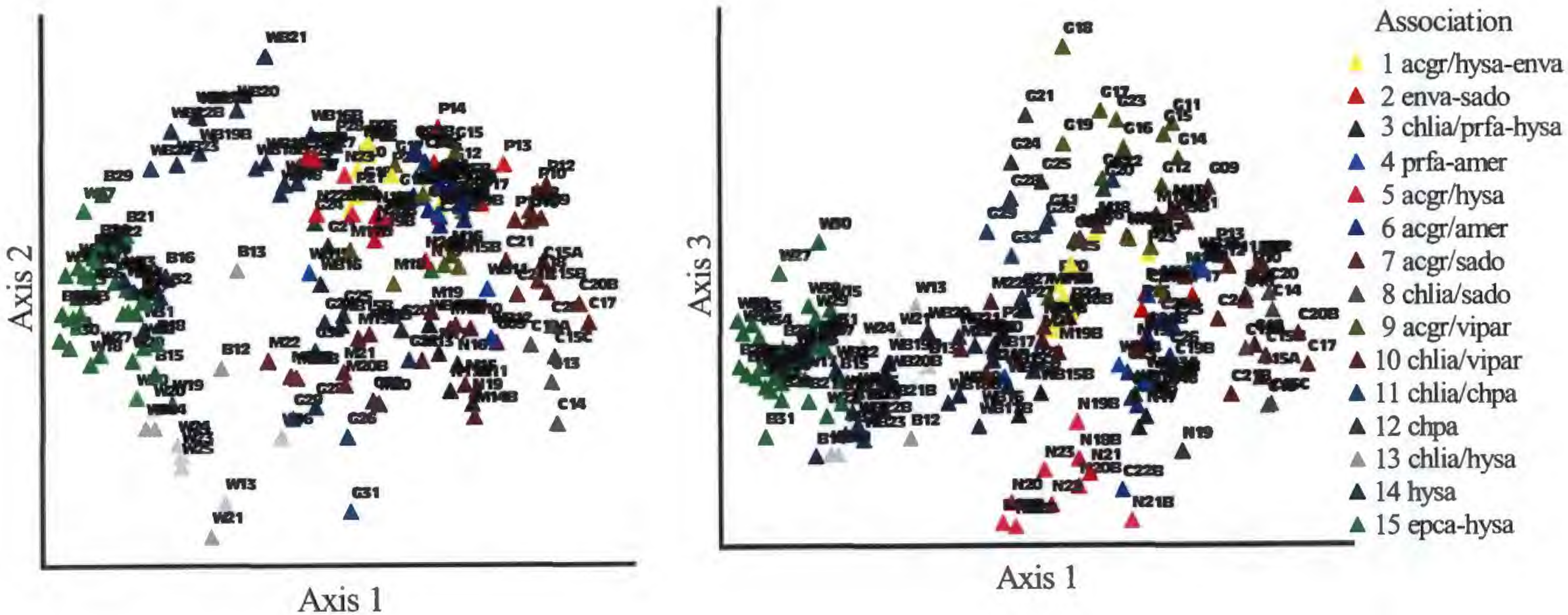

Figure 15. Bray-Curtis ordination diagrams for associations of 181 arroyos and washes of the eastern Mojave Desert. In legend, association numbers correspond to codes in Figure 11 and vegetation descriptions, and species codes correspond to codes in Appendix B.

Table 14. Coefficients of determination (r^2) between distances in the ordination space and distances in the original n-dimensional space for the canyon dataset and the arroyo/wash dataset.

	Axis					
	Canyon dataset			Arroyo/wash dataset		
R-squared	1	2	3	1	2	3
Incremental	.351	.338	.039	.449	.107	.091
Cumulative	.351	.689	.728	.449	.556	.647

Table 15. Pearson and Kendall correlations of species with the ordination axes in the canyon dataset. See Appendix B for species codes.

Axis 1		Axis 2	
Species	r	Species	r
A. Positive correlation			
pimo	0.720	prfa	0.728
yuba	0.653	acgr	0.683
cali4	0.600	vipar	0.548
pofel	0.585	stpa4	0.573
juos	0.543		
gusa2	0.533		
artr2g	0.530		
phst	0.517		
oper	0.514		
B. Negative correlation			
yusc2	-0.753	qutu	-0.687
lori3	-0.727	pofel	-0.628
base	-0.671	pemu	-0.625
juma	-0.668	gamu	-0.611
erfa2	-0.665	oper	-0.607
scba	-0.635	lichen	-0.604
acgr	-0.621	pimo	-0.599
erci6	-0.618	bocu	-0.559
brma3	-0.605	erwr	-0.533
sool	-0.566	gapa4	-0.531
tara	-0.559	moss	-0.522
tydo	-0.524	sivea	-0.514
gumi	-0.520	arpe2	-0.513
jume4	-0.512	elele	-0.507
acsp1	-0.511	rhtr	-0.504

axis (from left to right in Figure 10) is between samples of the *Quercus turbinella-Pinus monophylla* association of the granitic New York canyon and samples of the *Acacia greggii-Prunus fasciculata* association of the calcareous Gilroy canyon. The greatest separation along the second axis (from bottom to top) is between samples of the *Salix exigua-Baccharis sergiloides* association of the granitic Budweiser and Willow canyons and samples of the *Pinus monophylla-Garrya flavescens* association of the calcareous Clark canyon.

The ordination patterns also reveal substantial relationships between environmental factors and vegetation types since many of the environmental variables have significant correlations with the ordination axes (Table 16). At the left of the first axis (Figure 16), the *Quercus turbinella* and *Q. chrysolepis* types are strongly correlated with eastern geographic positions (UTME) and with higher amounts of boulder and plant basal area cover. At the right of this axis, the *Acacia greggii, Prunus fasciculata* and *Chilopsis linearis* types are strongly correlated with higher amounts of gravel, cobble, and non-native plant cover and have western geographic positions. Along the bottom of second axis, the *Baccharis sergiloides* and *Salix exigua* types are strongly correlated with higher amounts of fine sediment, bedrock, and non-native plant cover while they have lower elevation and southern geographic position. At the top of this axis, the *Prunus fasciculata, Salvia dorrii, Pinus monophylla, Quercus turbinella, Q. chrysolepis*, and types are strongly correlated with northern geographic positions (UTMN), higher elevation, and higher tree cover. The *Baccharis sergiloides, Salix exigua,* and *Acacia*

Table 16. Pearson and Kendall correlations of environmental variables with the ordination axes in the canyon dataset. See Appendix C for sample characteristic codes.

Sample Characteristic	Axis 1 r	Axis 1 tau	Axis 2 r	Axis 2 tau	Axis 3 r	Axis 3 tau
No. Species	-0.104	-0.090	-0.007	-0.006	0.527	0.326
Total Veg C	-0.121	-0.091	0.247	0.230	0.253	0.154
Tree C	-0.467	-0.395	0.510	0.426	0.394	0.232
Shrub C	0.199	0.155	-0.043	0.000	0.172	0.079
Ground C	0.127	0.120	-0.036	-0.010	0.012	-0.038
Non-native C	0.515	0.398	-0.407	-0.309	0.098	0.050
UTME	-0.663	-0.383	0.357	0.241	-0.304	-0.087
UTMN	-0.332	-0.167	0.750	0.664	0.213	0.119
Elevation	-0.353	-0.242	0.685	0.500	0.608	0.456
Width	0.391	0.416	0.104	0.056	-0.036	-0.038
Slope %	-0.272	-0.222	0.156	0.164	0.582	0.313
Aspect	0.646	0.459	-0.537	-0.351	-0.047	0.026
Fine %	0.164	-0.005	-0.738	-0.490	-0.201	-0.163
Bedrock %	-0.341	-0.347	-0.466	-0.317	-0.022	-0.029
Gravel %	0.557	0.412	0.199	0.066	-0.106	-0.030
Cobble %	0.456	0.263	0.471	0.380	0.169	0.132
Stone %	-0.092	-0.056	0.264	0.230	0.155	0.031
Boulder %	-0.624	-0.369	0.020	-0.060	-0.068	-0.015
Litter %	-0.480	-0.415	0.332	0.313	0.478	0.124
Basal C	-0.576	-0.479	0.189	0.145	-0.101	-0.148
Fines C	0.004	-0.017	-0.667	-0.506	-0.185	-0.157
Bedrock C	-0.471	-0.338	-0.501	-0.346	0.012	-0.016
Gravel C	0.360	0.469	0.086	0.083	-0.071	-0.042
Cobble C	0.205	0.294	0.224	0.395	0.021	0.121
Stone C	0.101	-0.026	0.219	0.311	0.031	0.041
Boulder C	-0.326	-0.292	-0.074	-0.051	-0.052	-0.048
Litter C	-0.226	-0.240	0.187	0.164	0.298	0.128

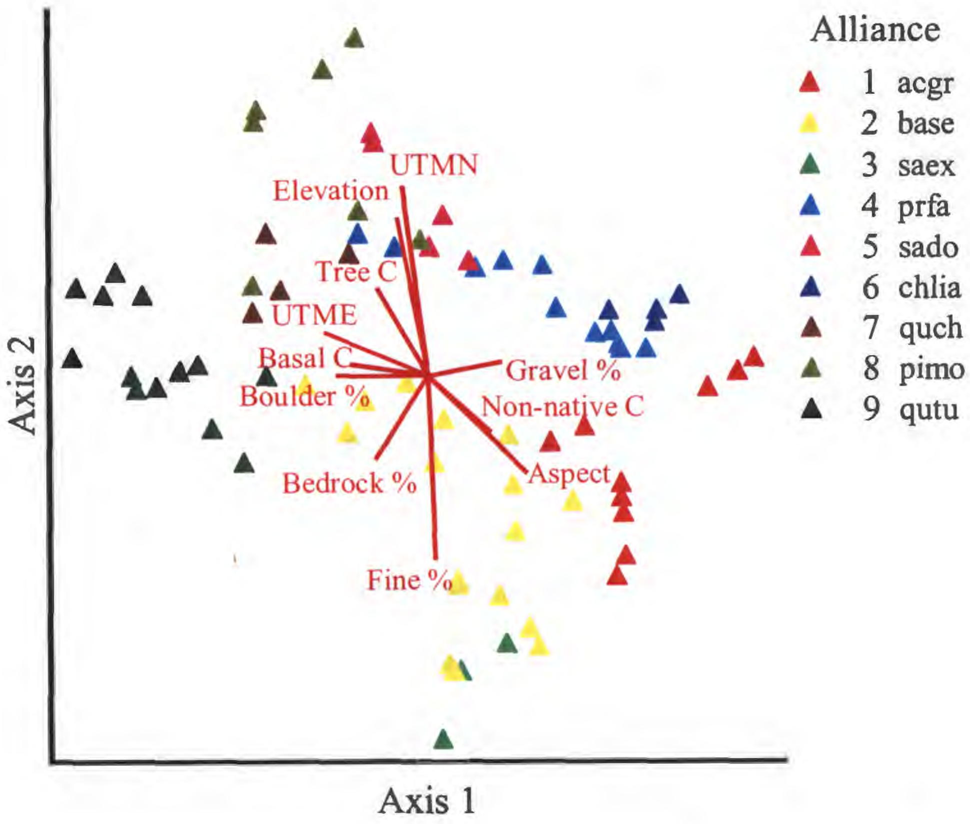

Figure 16. Bray-Curtis ordination diagram of canyon alliances with overlay of environmental and floristic variables (r>0.5). In legend, alliance numbers correspond to codes in Figure 6 and vegetation descriptions, and species codes correspond to codes in Appendix B.

greggii types are correlated with warmer aspects while the *Pinus monophylla, Salvia dorrii, Quercus turbinella,* and *Q. chrysolepis* types are correlated with cooler aspects.

The ordination along axis 2 also separated granitic samples on the bottom from calcareous samples on the top (Figure 16). Indicator Species Analysis provided significance values for species grouped on geologic substrate (Table 17), and the indicator species are related to specific vegetation types. Twenty-six canyon species are significant indicators ($p < 0.01$) for granite, including *Eriogonum fasciculatum, Lotus rigidus, Brickellia californica, Yucca schidigera,* and *Ericameria cuneata.* These species occur in the *Quercus turbinella* alliance of the New York Mountains and the *Baccharis sergiloides* and *Salix exigua* alliances of the Granite and Providence mountains. Also, 12 species are weakly correlated ($p< 0.05$) with granite, occurring in the *Baccharis sergiloides* associations.

Another 27 species are significant indicators for limestone, such as *Opuntia phaeacantha, Penstemon palmeri, Purshia mexicana, Tridens muticus, Brickellia multiflora, Gaura coccinea,* and *Agave utahensis* (Table 17). These species occur in lower elevation alliances of *Prunus fasciculata* in Providence and Clark mountains and *Chilopsis linearis* in the Providence Mountains. Other significant indicators such as *Eriogonum heermanii, Hedeoma nanum, Cercocarpus intricatus, Erigeron utahensis,* and *Maurandya antirrhiniflora* occur in the higher elevation alliances of *Pinus monophylla* in the Clark and Providence Mountains and *Quercus chrysolepis* in the Providence Mountains. Lastly, 12 species are weakly correlated with limestone, occurring in the *Prunus, Chilopsis,* and *Pinus* types.

Table 17. Indicator species and values for geologic substrate in the canyon dataset. The number of samples is denoted by n, and indicator value by IV. See Appendix A for complete taxonomic nomenclature (for subspecies and varieties).

A. Granite, n=41

Species	IV
1. Only (p<0.01)	
Baccharis sergiloides	90
Eriogonum fasciculatum	63
Eriogonum wrightii	48
Schismus barbatus	37
Ericameria cuneata	34
Quercus turbinella	32
Juncus macrophyllus	29
Pellaea mucronata	27
Tamarix ramosissima	27
Bromus diandrus	24
Muhlenbergia rigens	24
Purshia tridentata	24
Sonchus oleraceus	24
Artemisia dracunculus	22
Polypogon monspeliensis	22
Agrostis viridis	20
Astragalus nutans	20
Datura wrightii	20
Dudleya pulverulenta	20
Juncus mexicanus	20
Lycium andersonii	20
Typha domingensis	20
2. Prefer (p<0.05)	
Lotus rigidus	66
Ericameria linearifolia	52
Brickellia californica	46
Yucca schidigera	39
3. Weakly prefer (p<0.05)	
Lichen	45
Gutierrezia microcephala	43
Bouteloua curtipendula	22
Galium munzii	22
Bothriochloa barbinodis	17
Salix exigua	17
Carex alma	15
Hymenoclea salsola	15
Penstemon stephensii	15
Senecio flaccidus	15
Sisyrinchium halophilum	15
Sporobolus cryptandrus	15

B. Limestone

Species	IV
1. Only (p<0.01)	
Purshia mexicana	71
Eriogonum heermanii	37
Brickellia multiflora	36
Hedeoma nanum	33
Artemisia tridentata	24
Cercocarpus intricatus	24
Erigeron utahensis	24
Gaura coccinea	24
Arenaria macradenia	21
Cheilanthes feei	21
Maurandya antirrhiniflora	21
Agave utahensis	18
Chrysothamnus nauseous	18
Escobaria vivipara	18
Heliomeris multiflora	18
Menodora scoparia	18
2. Prefer (p<0.05)	
Opuntia phaeacantha	86
Penstemon palmeri	76
Yucca baccata	73
Prunus fasciculata	58
Thamnosma montana	55
Gutierrezia sarothrae	48
Tridens muticus	38
Crust	30
Galium angustifolium	32
Salvia dorrii	29
Garrya flavescens	25
3. Weakly prefer (p<0.05)	
Ephedra viridis	45
Castilleja linearifolia	35
Achnatherum parishii	29
Echinocereus triglochidiatus	27
Mirabilis pumilis	26
Tragia ramosa	24
Phlox stansburyi	19
Agave deserti	16
Krameria erecta	16
Astragalus lentiginosus	15
Eriogonum inflatum	15
Eriogonum microthecum	15

Bray-Curtis ordination of the arroyo/wash datasets

The first three axes of the Bray-Curtis ordination account for 64.7% of the total variation in the species composition data (Table 14). The first axis is the most interpretable axis, accounting for 44.9% of the variation. The second and third axes account for 10.7% and 9.1% of the variation, respectively.

The ordination patterns of species in sample space support the classification of vegetation types (Figure 14 and 15), as many species are strongly correlated ($r>0.5$) with the first axis (Table 18). The greatest separation of vegetation types along axis 1 (from left to right in Figure 15) is between samples of the *Ephedra californica-Hymenoclea salsola* association in the Granite Mountains and samples of the *Acacia greggii-Salvia dorrii* and *Chilopsis linearis-Salvia dorrii* associations in the Clark and Providence mountains.

The ordination patterns also reveal strong relationships between environmental factors and vegetation types since many of the quantitative environmental and floristic variables have significant correlations with the ordination axes (Table 19). Axis 1 is primarily correlated with surface rock cover (fine, cobble, and stone), ground cover of plants, northern geographic position (UTMN), elevation, and number of species per sample.

Along the left side of axis 1 (Figure 17), the *Ephedra californica* and *Hymenoclea salsola* vegetation types are highly correlated ($r>0.5$) with greater fine sediment cover, while they have lower species richness, elevation, and slope as well as southern and

Table 18. Pearson and Kendall correlations of species with the ordination axes in the arroyo/wash dataset. See Appendix B for species codes.

Axis 1		Axis 2		Axis 3	
Species	r	Species	r	Species	r
A. Positive correlation					
pepap	0.727			brma	0.604
sado4	0.709			vipar	0.652
acgr	0.647			stpa	0.550
erpu8	0.592				
opapcc	0.574				
trmu	0.564				
gumi	0.543				
amer	0.542				
acspl	0.533				
arpu9	0.529				
ecen	0.523				
epne	0.519				
B. Negative correlation					
isar	-0.714	chlia	-0.676	hysa	-0.675
scba	-0.701				
hysa	-0.570				

Table 19. Pearson and Kendall correlations of environmental variables with the ordination axes in the arroyo/wash dataset. See Appendix C for sample characteristic codes.

Sample Characteristic	Axis 1 r	Axis 1 tau	Axis 2 r	Axis 2 tau	Axis 3 r	Axis 3 tau
No. Species	0.790	0.622	-0.367	-0.222	0.022	0.089
Tot Veg C	0.245	0.226	0.103	0.075	0.155	0.142
Tree C	0.128	0.085	0.326	0.266	0.471	0.365
Shrub C	0.190	0.159	-0.037	-0.011	0.010	0.065
Ground C	0.667	0.533	-0.094	-0.057	0.189	0.187
Non-native C	-0.295	-0.219	0.069	-0.008	-0.490	-0.391
UTME	0.451	0.322	0.214	0.190	0.239	0.290
UTMN	0.616	0.568	-0.270	-0.212	0.080	0.268
Elevation	0.575	0.524	-0.188	-0.146	-0.206	-0.039
Width	-0.384	-0.218	0.226	0.198	-0.208	-0.139
Slope %	0.473	0.358	-0.220	-0.133	0.098	0.032
Aspect	-0.281	-0.143	0.188	0.125	-0.194	-0.198
Fine %	-0.666	-0.517	0.307	0.216	-0.404	-0.210
Gravel %	-0.216	-0.151	-0.062	-0.057	-0.142	-0.039
Cobble %	0.696	0.526	-0.271	-0.170	0.359	0.257
Stone %	0.641	0.476	-0.121	-0.098	0.456	0.324
Boulder %	0.382	0.312	-0.043	-0.049	0.347	0.253
Bedrock %	0.101	0.134	-0.064	-0.045	0.001	0.060
Litter %	0.028	-0.030	0.229	0.199	0.391	0.282
Basal C	0.190	0.130	0.054	0.089	0.410	0.279
Fines C	-0.695	-0.547	0.283	0.203	-0.286	-0.198
Gravel C	-0.186	-0.170	-0.047	-0.026	-0.056	0.002
Cobble C	0.672	0.508	-0.211	-0.145	0.412	0.251
Stone C	0.607	0.472	-0.179	-0.129	0.395	0.281
Boulder C	0.397	0.316	-0.166	-0.108	0.369	0.254
Bedrock C	0.168	0.142	-0.089	-0.053	0.020	0.070
Litter C	-0.098	-0.107	0.101	0.136	0.246	0.224

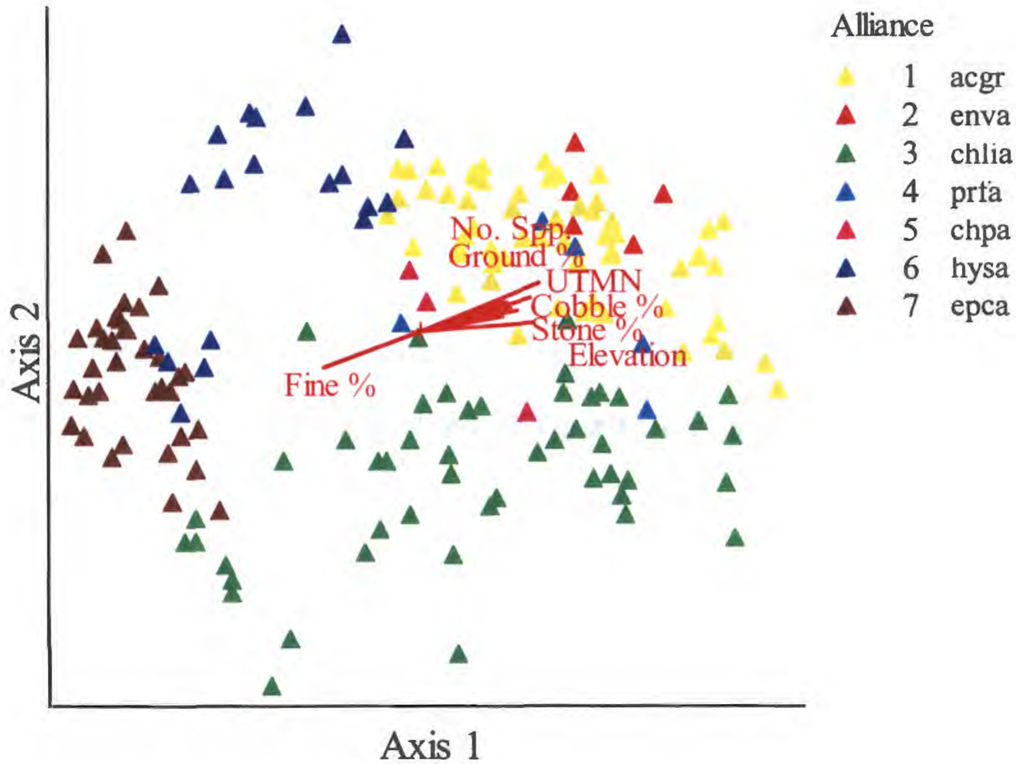

Figure 17. Bray-Curtis ordination diagram of arroyo and wash alliances with overlay of environmental and floristic variables (r>0.5). In legend, alliance numbers correspond to codes in Figure 11 and vegetation descriptions, and species codes correspond to codes in Appendix B.

western geographic positions. On the right of this axis, the *Acacia greggii, Encelia virginensis, Prunus fasciculata,* and *Chilopsis linearis* vegetation types are correlated ($r>0.45$) with eastern and northern geographic positions (UTME and UTMN), with higher species richness, elevation, and percent slope, and with higher amounts of total ground cover, cobble, and stone.

The ordination along axis 1 also separated granitic samples on the left side from calcareous samples on the right side (Figure 17). Indicator Species Analysis generated significant indicators for the geologic substrates in the arroyo and wash positions (Table 20), which are related to vegetation assemblages. Further, more than four times the number of species were highly correlated ($p<0.01$) with limestone as compared to granite. Some nine species are highly correlated with granite, such as *Isomeris arborea, Senecio flaccidus* var. *monoensis,* and *Opuntia ramosissima.* These species occur in the *Hymenoclea salsola* and *Ephedra californica* alliances. Only two species are weakly correlated with granite, which occur in the *Ephedra* type. Another 42 indicator species are correlated with limestone, such as *Erioneuron pulchellum, Salvia dorrii, Penstemon palmeri, Stephanomeria pauciflora, Oenothera caespitosa,* and *Tridens muticus.* These species occur in the *Acacia greggii, Chilopsis linearis, Prunus fasciculata,* and *Encelia virginensis* alliances of the Clark and Providence mountains.

Relationship of vegetation types to existing classifications

In the condensed description of alliances in this study (Table 21), the source field compares the alliances found solely in my study with the alliances found also by Thomas

Table 20. Indicator species and values for geologic substrate in the arroyo/wash dataset. The number of samples is denoted by n, and indicator value by IV. See Appendix A for complete taxonomic nomenclature (for subspecies and varieties).

A. Granite, n=89

Species	IV	Species	IV	Species	IV
1. Only (p<0.01)		2. Prefer (p<0.01)		*Pholisma arenaria*	16
Ephedra californica	55	*Hymenoclea salsola*	69	3. Weakly prefer (p<0.05)	
Isomeris arborea	55	*Schismus barbatus*	63	*Ambrosia dumosa*	24
Opuntia ramosissima	23	*Senecio flaccidus*	28	*Senna armata*	21
Eriogonum plumatella	16	*Psorothamnus arborscens*	17		

B. Limestone, n=92

Species	IV	Species	IV	Species	IV
4. Only (p<0.01)		*Gaura coccinea*	21	*Viguiera parishii*	39
Penstemon palmeri	69	*Mirabilis pumilis*	20	*Ambrosia eriocentra*	38
Oenothera caespitosa	46	*Ephedra viridis*	19	*Gutierrezia microcephala*	33
Echinocereus engelmannii	40	*Encelia farinosa*	18	*Chlilopsis linearis*	32
Tridens muticus	38	*Allionia incarnata*	17	*Thamnosma montana*	32
Yucca baccata	36	5. Prefer (p<0.01)		*Mirabilis bigelovii*	30
Aristida purpurea	37	*Erioneuron pulchellum*	66	*Phoradendron californicum*	25
Gutierrezia sarothrae	32	*Encelia virginensis*	59	*Muhlenbergia porteri*	24
Bebbia juncea	29	*Eriogonum inflatum*	58	*Physalis hederifolia*	24
Psilostrophe cooperi	28	*Stephanomeria pauciflora*	56	*Opuntia basilaris*	21
Achnatherum speciosum	24	*Acacia greggii*	55	*Chyrsothamnus paniculatus*	19
Chamaesyce albomarginata	24	*Bromus madritensis*	55	*Krameria ereta*	19
Opuntia phaeacantha	23	*Sphaeralcea ambigua*	53	*Physalis crassifolia*	17
Yucca baccata	23	*Salvia dorrii*	51	6. Weakly prefer (p<0.05)	
Escobaria vivipara	22	*Ephedra nevadensis*	48	*Salazaria mexicana*	32
		Opuntia acanthocarpa	45		

Table 21. Source and environmental characteristics of the alliances (with at least three replicate samples). Source codes are + for types solely in my study and * for types in Thomas et al. (1999). Position codes are C=canyon, A=arroyo, and W=wash. Elevation rounded to the and aspect are nearest 25 m and 30^{o}, respectively. Geology codes are G=granite and L=limestone. See vegetation descriptions in results for full alliance name:

Alliance	Source	Water course	Position	Elevation range (m)	Geology	Aspect (clockwise)	Surface rock
Acacia greggii	*	Budweiser, Gilroy, Mitchell, Pachalka, Clark, New York	C, A, W	850-1575	G, L	E-NNE	gravel
Baccharis sergiloides	+	Budweiser, Willow, Winston	C	1100-1600	G	ESE-NE	fine, gravel
Salix exigua	+	Budweiser, Willow	C	1200-1500	G	SSE-WSW	gravel, bedrock
Prunus fasciculata	*	Winston, Gilroy, Mitchell, Pachalka, Clark	C, A	1150-1700	G, L	E-NNW	gravel, cobble, boulder
Salvia dorrii	+	Pachalka, Clark	C, A	1200-1700	L	WSW-N	gravel, cobble
Chilopsis linearis	+	Budweiser, Willow, Winston, Mitchell, Gilroy, New York, Clark	lower C, A, W	725-1475	G, L	E-N	fine, gravel, cobble
Quercus chrysolepis	+	Winston, Mitchell, Gilroy	upper C	1450-1750	G, L	NW-NE	boulder
Pinus monophylla	*	Budweiser, Winston, Mitchell, Pachalka, Clark	middle to upper C	1325-1850	G, L	S-NE	gravel to bedrock
Quercus turbinella	+	New York	C	1225-1675	G	W-E	gravel, boulder, bedrock
Encelia virginensis	*	Pachalka	A	1225-1375	L	SSW-W	cobble, gravel
Chrysothamnus paniculatus	*	Willow, Gilroy	W	925-1150	G, L	E-SSW	fine, gravel

Table 21. Continued

Alliance	Source	Water course	Position	Elevation range (m)	Geology	Aspect (clockwise)	Surface rock
Hymenoclea salsola	*	Budweiser, Willow, Winston	A, W	850-1100	G	S-NW	gravel
Ephedra californica	*	Budweiser, Willow	A, W	850-1075	G	ESE-N	fine, gravel

et al. (1999). Of the 13 alliances that I recognized in this localized study with more than three replicate samples (with n≥3), Thomas et al. (1999) provided data for seven in the Mojave Desert (with n≥3). I documented six additional alliances, which are restricted types in the Mojave Desert but are widespread elsewhere (see discussion). Of my 30 analyzed associations (with n≥3), Thomas et al. (1999) provided data for four (with n≥3). I documented 24 additional associations.

Vegetation descriptions

I described my vegetation types based on species composition and habitat (Kent and Coker 1992), with the condensed description in Table 21. Further, the alliances are listed in Appendix D along with the sample locations. Indicator species listed in the vegetation type descriptions are presented in Appendices H to K from Indicator Species analyses of the canyon and arroyo/wash datasets. The group numbers of alliances and associations, which are found both in the Indicator Species analyses and in vegetation descriptions, correspond to those in the dendrograms (Figures 6 and 11).

I adhere to the following conventions in the vegetation descriptions: Subspecies and variety names are not included in the descriptions; complete taxonomic nomenclature is found in Appendix A. The alliance and associations names comply with the national vegetation classification system (The Nature Conservancy 1999). However, I will use only the scientific name without the physiognomy and habitat descriptors when referring to the alliances elsewhere in the text. For habit, short shrubs are those from 0.5 to 1 m and tall shrubs are between 1-3 m. Indicator species listed are in descending order of indicator value, and common associates listed are in alphabetical order. Some vegetation types lack indicator species, and they are defined by the dominant plants and common associates. When information such as structure or habitat is the same for the alliance and its association, it is presented only for the alliance description. The number of samples (n) is given at the end of each type.

Stands with at least three replicate samples

Acacia greggii Shrubland Alliance
Canyon alliance 1, Arroyo/wash alliance 1

Acacia greggii is the characteristic or dominant canopy shrub, but species composition is extremely variable among the stands. Structure is diverse with an intermittent deciduous tall shrub overstory, an intermittent deciduous short to tall shrub understory, and an open ground layer. An emergent tree layer is sometimes present. Indicator species are *Penstemon palmeri, Erioneuron pulchellum, Opuntia acathocarpa var. coloradensis, Ephedra nevadensis, Stephanomeria pauciflora, Sphaeralcea ambigua,* and *Eriogonum inflatum.* Common associates are *Ambrosia eriocentra, Bebbia juncea, Gutierrezia sarothrae, Hymenoclea salsola, Larrea tridentata, Salazaria mexicana,* and *Salvia dorrii.*

This alliance occurs in canyons, arroyos, and washes on granite and limestone usually below 1500 m. Aspect is highly variable. Over half the ground surface is covered in gravel. Soil is little developed with texture of coarse to fine sand. This alliance is divided into six associations (n=55):

Acacia greggii/Prunus fasciculata association (Canyon association 1)

Acacia greggii and *Prunus fasciculata* are important overstory shrubs with about equal cover (over 2%). *Viguiera parishii* sometimes compares in cover in the understory. Structure is an intermittent deciduous tall shrub overstory and intermittent deciduous short shrub and ground layers. Indicator species are *Hymenoclea salsola, Keckiella antirrhinoides, Bromus trinii,* and *Penstemon stephensii.* Common associates are *Achnatherum speciousum, Artemisia ludoviciana, Bromus madritensis, Encelia virginensis, Ephedra viridis, Euphorbia incisa, Gutierrezia sarothrae,* and *Phoradendron californicum.*

This association occurs in lower canyon bottoms and arroyos below 1500 m. It is found on granite in Budweiser drainage of the Granite Mountains and on limestone in Gilroy drainage of the Providence Mountains. Ground surface is mostly gravel and cobble. Soil texture is coarse to medium sand (n=10).

Acacia greggii/ Hymenoclea salsola-Encelia virginesis (Arroyo/wash association 1)

Acacia greggii is the characteristic canopy shrub with average cover less than 2% while *Hymenoclea salsola* and *Encelia virginensis* dominate in the mid-canopy with average cover of 5 and 2.5%, respectively. There are no indicator species. Common associates are *Ambrosia eriocentra, Brickellia incana, Lycium andersonii, Mirabilis bigelovii, Penstemon palmeri*, and *Salazaria mexicana.*

This association occurs in braided washes below 1300 m with 0-3 m high alluvial banks. It is found on limestone below the Clark Mountains in Pachalka water course. Soil texture varies from medium to fine sand (n=12).

Acacia greggi/Hymenoclea salsola association (Arroyo/wash association 5)

Acacia greggii is an important canopy shrub and *Hymenoclea salsola* is an important mid-canopy shrub, both with average cover of about 5%. Indicator species are *Lycium cooperi, Yucca schidigera*, and *Eriogonum plumatella*. Common associates are *Adenophyllum cooperi, Ambrosia eriocentra, Brickellia incana, Ephedra nevadensis, Krameria erecta, Larrea tridentata, Salvia dorrii, Salazaria mexicana,* and *Yucca schidigera.*

This association occurs in braided washes below 1200 m. It is on granite below the New York Mountains in northwesterly New York drainage. Gravel and fine sediment cover over 75% of the ground surface. Soil texture is medium sand (n=10).

Acacia greggii/Ambrosia eriocentra association (Arroyo wash association 6)

Acacia greggii is the dominant canopy shrub with average cover of 6% while *Ambrosia eriocentra* is the dominant mid-canopy shrub with average cover of 3-4%. There are no indicator species. Common associates are *Adenophyllum cooperi, Encelia virginensis, Ephedra nevadensis, Eriogonum fasciculatum, Erioneuron pulchellum, Gutierrezia microcephala, Hymenoclea salsola, Larrea tridentata, Phoradendron californicum, Salvia dorrii,* and *Stephanomeria pauciflora.*

This association occurs in washes on limestone below 1400 m. It is found below the Clark Mountains in Clark drainage. Over a quarter of the ground surface is cobble and fine sediment. Petrocalcic soil horizons are sometimes exposed in the channels. Soil texture is coarse sand (n=10).

Acacia greggii/Salvia dorrii association (Arroyo/wash association 7)

Acacia greggii is the dominant canopy shrub and *Salvia dorrii* is the dominant mid-canopy shrub, both averaging about 5% cover. *Ambrosia eriocentra* and *Prunus fasciculata* sometimes compare in cover. An emergent tree layer of *Chilopsis linearis* sometimes occurs. Indicator species are *Coleogyne ramosissima, Mirabilis multiflora, Fallugia paradoxa, Opuntia phaeacantha,* and *Rhus trilobata*. Common associates are *Achnatherum speciousum, Adenophyllum coorperi, Encelia virginensis, Krameria erecta, Opuntia acanthocarpa, Stephanomeria pauciflora,* and *Tridens muticus.*

This association occurs in arroyos and upper washes from 1250 to 1500 m and with 4-7% slopes and 10-50 m widths. It is found on limestone below the Clark Mountains in the Clark and Pachalka drainages. Over 80% of the ground surface is covered by gravel and cobble. Soil texture varies from coarse to fine sand (n=14).

Acacia greggii/Viguiera parishii association (Arroyo/wash association 9)

Acacia greggii is the dominant canopy shrub, and *Viguiera parishii* is the dominant mid-canopy shrub, both with average cover of around 4-5%. Indicator species are *Epehdra viridis, Yucca schidigera, Thamnosma montana,* and *Ferocactus* *cylindraceus*. Common associates are *Eriogonum fasciculatum, Erioneuron pulchellum, Gutierrezia sarothrae, Larrea tridentata, Psilostrophe cooperi* and *Salvia dorrii.*

This association occurs in arroyos below 1300 m on 3-7% slopes. It is found on limestone below the Providence Mountains in Gilroy and Mitchell drainages. Gravel and cobble cover more than 80% of the ground surface. Soil texture is medium sand (n=9).

Baccharis sergiloides Intermittently Flooded Shrubland Alliance
Canyon alliance 2

Baccharis sergiloides is the dominant canopy shrub with over 3% cover. The structure is an open to continuous deciduous tall shrub overstory, an intermittent short shrub understory, and a sparse to intermittent ground layer. Sometimes emergent broad-leaved evergreen and coniferous trees occur such as *Populus fremontii, Salix* spp. and *Pinus monophylla*. Indicator species are *Eriogonum fasciculatum, Gutierrezia microcephala, Lotus rigidus, Yucca schidigera, Ericameria linearifolia, Sphaeralcea ambigua, Acacia greggii, Opuntia acanthocarpa*, and *Erodium cicutarium,* and *Bromus madritensis*. Common associates are *Artemisia ludoviciana, Prunus fasciculata,* and *Rhus trilobata.*

This alliance is found in canyons above 1100 m with seasonal streamflow and around permanent springs. Microtopography is diverse, ranging from flat surfaces of gravel and exposed bedrock to 25 m high vertical waterfalls of bedrock and boulders. Over half of the ground surface is covered with gravel and fine sediment. Soils are usually little developed with texture varying from fine and coarse sand to medium sandy loam. This alliance is divided into three associations (n=20):

Baccharis sergiloides-Prunus fasciculata association (Canyon association 2)

Baccharis sergiloides and *Prunus fasciculata* are important canopy shrubs that share in dominance both with above 3% cover. Structure includes an intermittent deciduous tall shrub overstory and an open ground layer. There are no indicator species. Common associates are *Achnatherum speciosum, Artemisia ludoviciana, Brickellia californica, Epedra viridis, Euphorbia incisa, Hymenoclea salsola, Salvia mohavensis,* and *Stephanomeria pauciflora.*

This association occurs in canyons above 1100 m with slopes of over 10%. It is found in water courses of northerly and southerly exposures in Budweiser and Winston canyons of the Granite and Providence mountains. The microtopography ranges from steep-walled bottoms to open basins. Bedrock and boulder drops with water are common. Soil texture is coarse to medium sand (n=4).

Baccharis sergiloides-Prunus fasciculata-Rhus trilobata association (Canyon association 3)

Baccharis sergiloides, *Prunus fasciculata,* and *Rhus trilobata* are important canopy shrubs. *Baccharis* has 5-15% cover, while *Prunus* and *Rhus* both have over 2% cover. Structure includes a moderately dense deciduous tall shrub overstory and an intermittent ground layer, sometimes with emergent broad-leaved evergreen and coniferous trees. Indicator species are *Purshia tridentata, Eleocharis parishii, Artemisia dracucunculus, Polypogon monspeliensis, Bromus tectorum,* and *Mirabilis multiflora.* Common associates are *Artemisia ludoviciana, Brickellia californica, Eriogonum* *wrightii, Juncus mexicanus, Mirabilis pumila, Opuntia erinacea, Penstemon palmeri, Pinus monophylla,* and *Rhamnus tomentella.*

This association occurs in middle to upper canyons primarily above 1300 m. It was found on granite in Winston canyon of the Providence Mountains of northwest to northeast exposures. A matrix of bedrock, boulders, and sand exist. Soil texture varies from coarse sand to medium-fine sandy loam (n=5).

Baccharis sergiloides/Muhlenbergia rigens association (Canyon association 4)

Baccharis sergiloides is the dominant canopy shrub with 5-50% cover. *Muhlenbergia rigens* is a characteristic or dominant understory grass with less than 1 to over 20% cover. Structure includes a moderately dense deciduous tall shrub overstory and an intermittent ground layer. Indicator species are *Juncus macrophyllus, Juncus mexicanus, Sonchus oleraceus, Typha domingensis, Tamarix ramosissima, Schismus barbatus,* and *Oenothera primiveris.* Common associates are *Achnatherum speciosum, Arabis pulchra, Brickellia californica, Ericamerica cuneata, Oenothera caespitosa*, and *Rhus trilobata.*

This association occurs in spring-fed canyon bottoms with running water and standing pools from 1100 to 1700 m. It is found on granite in the Granite Mountains. Microtopography is diverse from flat sandy stretches to vertical waterfalls and exposed mounds of smoothed bedrock. Soil texture is fine to coarse sand (n=11).

Salix exigua Temporarily Flooded Shrubland Alliance
Canyon alliance 3

Salix exigua/Baccharis sergiloides association (Canyon association 5)

Salix exigua is the dominant canopy species with cover from about 5 to 60%. *Baccharis sergiloides* is the dominant understory species with cover from about 6 to 20%. Structure is a moderately dense to continuous deciduous tall shrub to small tree overstory, a deciduous short to tall shrub understory, and a sparse to an intermittent ground layer. There are no indicator species. Common associates are *Acacia greggii, Achnatherum speciosum, Brickellia californica, Bromus madritensis, Dudleya pulverulenta, Epilobium canum, Eriogonum fasciculatum, Juncus macrophyllus, Juncus mexicanus, Muhlenbergia rigens,* and *Sonchus oleraceus.*

This association occurs in upper to lower sections of canyon bottoms where permanent water is present. It is found above 1100 m in Willow and Budweiser canyons of the Granite Mountains. Microtopography varies from smoothed bedrock escarpments and waterfalls to flat sandy areas. Soil is little to moderately developed with texture from medium sand to medium fine sandy loam. (n=4).

Prunus fasciculata Shrubland Alliance
Canyon alliance 4, Arrroy/wash alliance 4

Prunus fasciculata is the dominant or characteristic canopy shrub with an average of over 5% cover. Structure is complex with an intermittent deciduous tall shrub overstory and intermittent deciduous short shrub and ground layers. Emergent coniferous and deciduous flowering trees are sometimes present. Indicator species are *Opuntia* *phaeacantha, Purshia mexicana, Salvia mohavensis,* and *Gaura coccinea*. Common associates are *Acacia greggii, Achnatherum speciosum, Artemisia ludoviciana, Gutierrezia sarothrae, Penstemon palmeri, Physalis hederifolia, Rhus trilobata, Sphaeralcea ambigua, Thamnosma montana* and *Yucca baccata.*

This alliance occurs in upper to lower canyon bottoms of both northerly and southerly aspects above 1200 m. The canyons usually have steep bedrock walls. The alliance is found on limestone in the Providence and Clark Mountains at elevations above 1200 m. At least 80% of the ground surface is covered with gravel and cobble, and less than 5% is fine sediment. Soil is little developed with coarse to medium sand texture. This alliance is divided into three associations (n=14):

Prunus fasciculata-Purshia mexicana association (Canyon association 6)

Prunus fasciculata and *Purshia mexicana* are important canopy shrubs both with an average cover value of 7%. *Acacia greggii* also provides additional cover near 2%, typically less than half the percent cover of *Prunus*. Indicator species are *Eriogonum inflatum, Mirabilis bigelovii, Dudleya saxosa, Melica frutescens.* Common associates are *Artemisia ludoviciana, Echinocereus engelmannii, Euphorbia incisa, Gutierrezia sarothrae,* and *Galium angustifolium.*

This association occurs in middle to lower canyon bottoms above 1300 m. It is found on limestone in Gilroy Canyon of the Providence Mountains with southeastern exposures (n=3).

Prunus fasciculata (Canyon association 8)

Prunus fasciculata is the dominant with over 5% cover. *Acacia greggii* if present is typically with less than half the cover of *Prunus*. Indicator species are *Salazaria mexicana, Agave utahensis, Tragia ramosa,* and *Ambrosia eriocentra.* Common associates are *Acacia greggii, Brickellia multiflora, Ephedra viridis, Gaura coccinea, Oenothera caespitosa, Tridens muticus,* and *Physalis hederifolia.*

This association is found at elevations in lower to upper canyons above 1500 m with southerly to northerly exposures. Slope varies from around 5 to 20%. It occurs on limestone in the Gilroy and Mitchell drainages of the Providence Mountains (n=3).

Prunus fasciculata-Rhus trilobata association (Canyon association 9)

Prunus fasciculata and *Rhus trilobata* are important canopy shrubs with over 6% and 3% cover, respectively. There are no indicator species. Common associates include *Achnatherum speciousum, Artemisia ludoviciana, Gutierrezia sarothrae,* and *Purshia mexicana.*

This association occurs in upper to lower canyon bottoms above 1200 m. It is found in the Pachalka and Mitchell drainages of the Clark and Providence mountains above 1600 m (n=4).

Prunus fasciculata/Ambrosia eriocentra association (Arroyo/wash association 4)

Prunus fasciculata is the dominant canopy shrub with average cover of 5% and *Ambrosia eriocentra* is the dominant mid-canopy shrub with average cover of 8%.

Structure is an intermittent tall shrub overstory, an intermittent short shrub understory, and an open ground layer. There are no indicator species. Common associates are *Eriogonum fasciculatum, Hymenoclea salsola, Salvia dorrii, Senna armata, Senecio flaccidus,* and *Stephanomeria pauciflora.*

This association occurs in arroyos with deeply incised channels from 1100 to 1300 m with 4-7% slopes. The *Prunus fasiculata* alliance is commonly found in canyons, but this distinctive form occurs in arroyos. It is found on granite at the base of the Providence Mountains in Winston arroyo. Soil texture is coarse to medium sand (n=5).

Salvia dorrii Shrubland Alliance
Canyon alliance 5

Salvia dorrii undifferentiated (Association 10)

Salvia dorrii is the dominant canopy shrub with around 7% cover. Structure is diverse with intermittent cover of deciduous short shrubs and an emergent layer of coniferous trees and deciduous large shrubs. *Pinus monophylla, Prunus fasiculata, Fallugia paradoxa* or *Purshia mexicana* may dominate in the overstory with above 1% cover. Indicator species are *Coleogyne ramosissima, Heliomeris multiflora, Castilleja angustifolia,* and *Ericameria cooperi.* Common associates are *Yucca baccata* and *Rhus trilobata.*

This association occurs in lower canyons and upper arroyos at elevations above 1200 m. It is found on limestone in Clark canyon and below the Clark Mountains in Pachalka arroyo. More than 80% of the ground surface is covered with gravel, cobble, and stone. Soil texture is coarse sand (n=6).

Chilopsis linearis Intermittently Flooded Shrubland Alliance
Canyon alliance 6, Arroyo/wash alliance 3

Chilopsis linearis is the dominant canopy tree with cover at least 2%, but species composition is extremely variable among the stands. Structure is complex with an intermittent to semi-continuous canopy of deciduous small trees, an intermittent deciduous short to tall shrub understory, and an open ground layer. There are no indicator species. Common associates are *Acacia greggii, Bromus madritensis, Hymenoclea salsola, Sphaeralcea ambigua,* and *Stephanomeria pauciflora.*

This alliance occurs in lower canyons, braided arroyos, and upper washes on limestone and granite below 1500 m. Aspect and water course width are variable. Gravel covers 40-80% of the ground surface, but all other rock fragments are common. Soil is little developed with texture from coarse to medium sand. This alliance is divided into seven associations (n=54):

Chilopsis linearis/Prunus fasciculata association (Canyon association 7)

Chilopsis linearis is the dominant canopy tree with an average of over 10% cover. *Prunus fasciculata* is the dominant mid-canopy shrub with cover over 5%. *Viguiera parishii* sometimes compares in cover to *Prunus* with cover above 2%. Structure is an intermittent to moderately dense deciduous small tree overstory, an intermittent deciduous short to tall shrub understory, and open ground layer. Indicator species are *Physalis crassifolia, Brickellia multiflora*, and *Astragalus mohavensis*. Common associates are *Acacia greggii, Gutierrezia sarothrae, Opuntia phaeacantha, Penstemon palmeri, Purshia mexicana,* and *Yucca baccata.*

This association occurs in open, braided canyon bottoms below 1300 m with steep bedrock walls and northwesterly aspects. It is found on limestone in lower Mitchell canyon of the Providence Mountains. The ground surface is about 80% gravel and cobble. Fine sediments are few. Soil texture is coarse to medium sand (n=4).

Chilopsis linearis/Prunus fasciculata-Hymenoclea salsola association (Arroyo/wash association 3)

Chilopsis linearis is the dominant canopy tree with 5-15% cover. *Prunus fasciculata, Hymenoclea salsola,* and *Acacia greggii* are important mid-canopy shrubs with around 5% cover each. There are no indicator species. Common associates are *Ambrosia eriocentra, Salvia dorrii,* and *Salazaria mexicana.*

This association occurs in upper, braided arroyos below 1300 m on granite in eastern aspects. It is found at the base of the Providence and New York Mountains in Winston and New York drainages. Soil texture is primarily medium sand (n=6).

Chilopsis linearis/Salvia dorii association (Arroyo/wash association 8)

Chilopsis linearis is the dominant canopy tree with cover from 5-15%. *Salvia dorrii* is the dominant mid-canopy shrub with cover from 2-5%. *Acacia greggii* sometimes compares in cover with *Salvia*. There are no indicator species. Common associates are *Ambrosia eriocentra, Encelia virginensis, Gutierrezia microcephala, Salazaria mexicana,* and *Yucca breviflora.*

This association occurs in upper, braided arroyos from 1300 to 1500 m. It is found on limestone in the basin below Clark Peak in the Clark Mountains. Soil texture is medium sand (n=5).

Chilopsis linearis association (Arroyo/wash association 10a)

Chilopsis linearis is the dominant overstory species with at least 5% cover. Structure is an intermittent deciduous small tree overstory, an intermittent understory of deciduous and evergreen short to tall shrubs, and an open ground layer. *Bebbia juncea* var. *aspera* and/or *Hymenoclea salsola* sometimes dominates the understory. There are no indicator species. Common associates are *Encelia farinosa, Larrea tridentata, Oenothera caespitosa, Opuntia basilaris, Penstemon palmeri, Stephanomeria pauciflora*, and *Viguiera parishii.*

This association occurs in braided washes below 900 m. It is found on limestone below the Providence Mountains as a continuous stand in middle to lower Mitchell wash. Slopes are 3-5%. Gravel and cobble cover at least 75% of the ground. Soil texture is medium sand. Petrocalcic horizons are sometimes exposed (n=9).

Chilopsis linearis/Viguiera parishii association (Arroyo/wash association 10b)

Chilopsis linearis is the dominant canopy tree with cover of 5-30%. *Viguiera parishii* is the dominant mid-canopy shrub with cover of 2-7%. *Acacia greggii* sometimes compares in cover to *Viguiera*. There are no indicator species. Common associates are *Bebbia juncea, Encelia farinosa, Erioneuron pulchellum, Gutierrezia sarothrae, Larrea* *tridentata, Oenothera caespitosa, Opuntia acanthocarpa, Penstemon palmeri, Physalis crassifolia*, and *Stephanomeria pauciflora.*

This association occurs in arroyos and washes below 1300 m. It is found on limestone below the Providence Mountains as a continuous stand in Mitchell arroyo and upper wash and as a small stand in the Gilroy arroyo. Slopes are 4-8%. Gravel and cobble cover at least 75% of the ground. Soil texture is usually coarse, but sometimes medium or fine (n=8).

Chilopsis linearis/Chrysothamnus paniculatus association (Arroyo/wash association 11)

Chilopsis linearis is the dominant canopy tree with cover of 2-20%, and *Chrysothamnus paniculatus* is the dominant mid-canopy shrub with cover of 2-10%. Indicator species are *Physalis hederifolia, Brickellia incana, Eriogonum fasciculatum,* and *Cucurbita palmata.* Common associates are *Acacia greggii, Ambrosia eriocentra, Encelia virginensis, Hymenoclea salsola, Senna armata,* and *Stephanomeria pauciflora.*

This association occurs below 1200 m in gently sloping, braided washes. Wash width varies from 10-100 m. It is found below the Providence Mountains in the lower Gilroy drainage and into Barber Canyon Wash on mixed limestone and metasedimentary. Over 80% of the ground surface is covered gravel, cobble, and fine sediment. Soil texture is medium sand (n=8).

Chilopsis linearis/Hymenoclea salsola association (Arroyo/wash association 13)

Chilopsis linearis is the dominant canopy tree with cover from 1-40%.

Hymenoclea salsola is the dominant or characteristic mid-canopy shrub with cover from 1-10%. *Ephedra californica* and *Isomeris arborea* infrequently compare or exceed in cover to *Hymenoclea*. There are no indicator species. Common associates are *Acacia greggii, Bromus madritensis, Erodium cicutarium, Larrea tridentata, Senecio flaccidus,* and *Schismus barbatus.*

This association occurs in arroyos and on pediment below 1200 m. The water courses are braided and scoured, and they vary in aspect and width. It is found on granite below the Granite and Providence mountains in Budweiser, Willow, and Winston drainages. Over 80% of the ground surface is gravel and fine sediment. Soil texture is coarse to medium sand (n=18).

Quercus chrysolepis Forest Alliance
Canyon alliance 7

Quercus chrysolepis/Rhamnus ilicifolia association (Canyon association 11)

Quercus chrysolepis is the dominant canopy tree with cover over 20%. *Rhamnus ilicifolia* is the dominant mid-canopy shrub with cover over 3%. Structure is diverse with a semi-continuous evergreen broad-leaved tall shrub to small tree overstory, intermittent deciduous and broad-leaved evergreen shrub understory, and intermittent ground layer. Sometimes there are emergent coniferous small trees. Indicator species are *Lomatium parryi, Erigeron utahensis, Leymus salinus, Cheilanthes feei, Hedeoma nanum, Rhamnus tomentella, Arabis perennans, Agave deserti, Leptodactylon pungens,* and *Maurandya antirrhiniflora.* Common associates are *Brickellia californica, Garrya flavescens, Pinus monophylla, Rhus trilobata,* and *Yucca baccata.*

This association occurs in steep, incised upper canyon bottoms above 1400 m. Slopes are above 15% and aspects ranging from northwest to southeast. It is on granite and limestone in the Gilroy, Mitchell, and Winston drainages of the Providence Mountains. The ground surface is heterogeneous, with litterfall and all size rock types common except fine sediments. Soil varies in texture from coarse sand to moderately fine sandy clay loam (n=3).

Pinus monophylla Woodland Alliance

Canyon alliance 8

Pinus monophylla/Garrya flavescens association (Canyon association 12)

Garrya flavescens dominates the tree canopy with cover from 2-28%, and *Pinus monophylla* is a characteristic canopy tree from 1-7%. Structure is an intermittent to moderately dense broad-leaved evergreen and coniferous small tree overstory and intermittent deciduous shrub and ground layers. Indicator species are *Hymenoxys cooperi, Phlox stansburyi, Artemisia tridentata, Symphoricarpos longiflorus, Eriogonum microthecum*, and *Cercocarpus intricatus.* Common associates are *Prunus fasciculata, Purshia mexicana, Rhus trilobata, Fraxinus anomale, Ephedra viridis, Juniperus osteosperma, Rhamnus ilicifolia,* and *Rhamnus tomentella.*

This association occurs in north-facing canyons above 1300 m with 10-30% slopes. It is found along upper slopes in the Providence and Clark mountains on both granite and limestone. It occurs in the upper to middle Winston, Mitchell, and Clark drainages, especially between 1600 and 2000 m. Over 50% of the ground is covered with rock. Microtopography varies from vertical bedrock waterfalls and boulder drops to flat gravelly areas. Soil is diverse in texture and development, from sand to sandy loam (n=8, including one outlier sample).

Quercus turbinella Shrubland Alliance
Canyon alliance 9

Quercus turbinella is the dominant canopy shrub or tree. The structure is a tall shrub to small tree overstory of broad-leaved evergreen species and sometimes conifers that tend to densely dominate the banks of watercourses, while an intermittent short to tall shrub understory and an open ground layer occur in the middle of these watercourses. Indicator species are *Bouteloua curtipendula, Pellaea mucronata, Fallugia paradoxa, Eriogonum wrightii, Agrostis viridis,* and *Galium munzii.* Common associates are *Artemisia ludoviciana, Elymus elymoides,Gutierrezia sarothrae, Opuntia erinacea, Poa fendleriana, Rhus trilobata,* and *Yucca baccata.*

This alliance occurs in steep-walled canyon water courses and slopes of decomposed granite with boulders and smoothed bedrock surfaces between 1200-2000 m. It is found on cool, upper to lower canyon slopes in the New York canyon. The soils are typically little developed, with coarse to medium sand. This alliance is divided into two associations (n=13):

Quercus turbinella-Pinus monophylla association (Canyon association 13)

Quercus turbinella and *Pinus monophylla* are important canopy species with about 8% and 5% cover, respectively. *Fallugia paradoxa* and *Rhus trilobata* commonly occur as mid-canopy shrubs in the canyon bottoms. *Quercus chrysolepis* occurred in two of the samples and was a co-dominant species in the highest elevation (1655 m) sample with about 10% tree canopy cover. Indicator species are *Woodsia oregana, Asclepias asperula, Astragalus nutans,* and *Silene verecunda.* Common associates are *Arabis perennans, Artemisia ludoviciana, Brickellia californica, Castilleja linearifolia, Elymus elymoides, Galium munzii, Gutierrezia sarothrae, Juniperus osteosperma,* and *Poa fendleriana.*

This association occurs in upper canyons largely above 1500 m in deeply incised, granitic canyons and slopes. Rock outcrops are common, with boulders and bedrock covering 60-70% of the ground (n=5).

Quercus turbinella/Baccharis sergiloides association (Canyon association 14)

Quercus turbinella has a canopy of about 5-20%, and *Baccharis sergiloides* is the dominant mid-canopy shrub with about 4-8% cover. Indicator species are the understory herbs of *Erigeron divergens,* and *Bromus diandrus.* Common associates are *Artemisia ludoviciana, Elymus elymoides, Fallugia paradoxa, Forestiera pubescens, Gutierrezia sarothrae,* and *Rhus trilobata.*

This association occurs in lower to middle canyons from 1200 to 1500 m. It is found on granite with steep drops of bedrock and boulders, scoured rock surfaces, and pools of standing water. Boulders make up about 30% of the ground surface (n=8).

Encelia virginensis Shrubland Alliance
Arroyo/wash alliance 2

Encelia virginensis-Salvia dorrii association (Arroyo/wash association 2)

Salvia dorrii and *Encelia virginensis* are important canopy shrubs with over 5% and 2% cover, respectively. Structure is an intermittent overstory of deciduous short shrubs and an intermittent ground layer. Emergent tall shrubs of *Acacia greggii* sometimes occur. There are no indicator species. Common associates are *Aristida purpurea, Ephedra nevadensis, Hymenoclea salsola, Salazaria mexicana, Stephanomeria pauciflora,* and *Yucca baccata.*

This association occurs in arroyos from 1200 to 1400 m and with banks over 3 m high. It is found on limestone below the Clark Mountains in Pachalka drainage. Slopes are around 4-5%. Ground surface is over 80% gravel and cobble. Soil is little developed with medium sand texture (n=6).

Chrysothamnus paniculatus Shrubland Alliance
Arroyo/wash alliance 5

Chrysothamnus paniculatus undifferentiated (Arroyo/wash association 12)

Chrysothamnus paniculatus is dominant canopy shrub with cover over 5%. Structure is an intermittent overstory of deciduous and evergreen tall shrubs, and open to intermittent short shrub understory, and open ground layer. Emergent small trees of *Chilopsis linearis* sometimes occur. There are no indicator species. Common associates are *Ambrosia eriocentra, Encelia virginensis, Eriogonum fasciclatum, Hymenoclea salsola, Larrea tridentata, Physalis hererifolia, Salvia dorrii, Stephanomeria pauciflora,* and *Salvia dorrii.*

This alliance occurs in open, gently sloping washes below 1200 m. It is found below the Providence Mountains west of Gilroy Canyon in Barber Wash on mixed limestone and metasedimentary. Over 80% of the ground is covered by gravel, cobble, and fine sediment. Soil texture varies from medium to fine sand (n=4).

Hymenoclea salsola Shrubland Alliance
Arroyo/wash alliance 6

Hymenoclea salsola undifferentiated (Arroyo/wash association 14)

Hymenoclea salsola is the dominant canopy species with cover from 2-20%. *Larrea tridentata* infrequently compares in cover. Structure is an intermittent overstory of deciduous and evergreen tall shrubs and intermittent short shrub and ground layers. Indicator species are *Psorothamnus arborescens, Mirabilis bigelovii, Krameria grayi, Eriogonum fasciculatum,* and *Senna armata.* Common associates are *Ambrosia dumosa, Erodium cicutarium, Larrea tridentata, Schismus barbatus,* and *Stephanomeria pauciflora.*

This alliance occurs in washes, sometimes with well-defined banks up to 3 m high. It is found below 1150 m on slopes less than 5% with variable aspect. Stands occur on granite below the Granite and Providence mountains in Budweiser, Willow, and

Winston washes. The ground surface is primarily gravel and fine sediment. Soil texture is coarse to medium sand (n=14).

Ephedra californica Shrubland Alliance
Arroyo/wash alliance 7

Ephedra californica/Hymenoclea salsola association (Arroyo/wash association 15)

Ephedra californica and *Hymenoclea salsola* are important canopy shrubs with cover from 2-15% and 2-10%, respectively. Structure is an intermittent overstory of deciduous and evergreen tall shrubs and sparse ground layer. Indicator species are *Isomeris arborea, Opuntia ramosissima, Senecio flaccidus, Stillingia linearifolia* and *Pholisma arenaria.* Common associates are *Adenophyllum cooperi, Ambrosia dumosa, Erodium cicutarium, Larrea tridentata, Lycium andersonii* and *Schismus barbatus.*

This association occur in arroyos and washes, on pediment and alluvial fans below 1200 m. The watercourses have variable width from 10 to over 100 m, and variable aspect. Continuous stands are found in the Granite Mountains in Budweiser and Willow drainages. The ground is primarily covered with gravel and fine sediment. Soil texture is coarse to medium sand (n=38).

Unique Stands

Populus fremontii Temporarily Flooded Woodland Alliance

Populus fremontii/Baccharis sergiloides association

Populus fremontii is the dominant overstory tree species with continuous cover of about 25%. *Baccharis sergiloides* is the dominant understory shrub species with continuous cover under the *Populus*. Canopy structure is a continuous to open deciduous tree-layer with height below 20 m. Shrub and ground layer is moderately continuous. Common associates are *Epilobium canum, Gutierrezia microcephala, Juncus mexicanus, Oenothera caespitosa, Prunus fasciculata,* and *Rhus trilobata.*

This association occurs in desert watercourses that have a permanent water source. It is found in canyons and arroyos of the Granite Mountains below 1700 m, such as in upper Willow canyon. Fine sediment, gravel, and boulders are common. Soil is moderately developed with texture of medium fine sandy loam (n=1).

Psorothamnus spinosus Shrubland Alliance

Psorothamnus spinosus/Ephedra californica-Hymenoclea salsola association

Psorothamnus spinosus is the dominant canopy tree with cover of at least 2%. *Ephedra californica* and *Hymenoclea salsola* compare in cover to *Psorothamnus.* Structure is a deciduous small tree overstory, an open understory of evergreen and deciduous shrubs, and a sparse ground layer. Common associates are *Adenophyllum cooperi, Ambrosia dumosa, Isomeris arborea, Larrea tridentata,* and *Senecio flaccidus.*

This association occurs in gently sloping washes below 1000 m. It is found in the southern Mojave Desert, at the furthest south sample location below the Granite Mountains in Willow Wash. The stand is on granite with some volcanic rock fragments, with gravel and fine sediments prevailing. Soil texture is medium sand (n=2).

DISCUSSION

Environmental gradients

The patterns of vegetation in canyons, arroyos, and washes reflect the control of environmental factors at several different scales. I found three main factors influencing vegetation patterns across the study area: the topographic gradient, geologic substrate, and geographic position. The influences of these three factors vary depending on topographic position, as the environmental controls in canyons are different from those in arroyos and washes.

Topographic gradient

The importance of topography in controlling vegetation patterns is supported by the analyses of the complete, canyon, and arroyo/wash datasets. A topographic gradient is influential at the local scale, as a function of topographic position, elevation, aspect, amount of surface rock, sediment size, and disturbance; it results in available soil moisture and temperature gradients.

The topographic gradient was the first environmental control revealed in the classification and ordination of the complete dataset where canyons were placed in one group and arroyos and washes in another. The significance of this gradient was also emphasized by the canyon ordination through correlations of aspect, elevation, and surface rock cover with axes 1 and 2 (Figure 16) and by the arroyo/wash ordination through correlations of elevation and surface rock cover with axis 1 (Figure 17). The influence of topography in controlling vegetation patterns is apparent across all water courses, as every water course had at least one distinct alliance per topographic position (Appendix D). Further, vegetation types usually are associated with only one topographic position or with two similar positions.

The canyon position had the greatest number of species and alliances even though canyons covered less distance than did arroyos and washes. Plant habit was more diverse in canyons, where grasses, sod-forming rushes and sedges, herbs, cacti, small deciduous shrubs, large deciduous shrubs, large evergreen shrubs, and coniferous trees mixed together. Of the 15 alliances, six were exclusive to canyons (*Baccharis sergiloides*, *Pinus monophylla*, *Populus fremontii*, *Quercus chrysolepis*, *Q. turbinella*, and *Salix exigua*). A greater degree of habitat heterogeneity and more available water may explain this diversity in canyons.

When considering the lower topographic positions, *Encelia virginensis* was the only alliance associated particularly with arroyos. *Chrysothamnus paniculatus* and *Psorothamnus spinosus* were found exclusively in washes. The *Prunus fasciculata* alliance was found mostly in canyons and sometimes in arroyos, and *Ephedra californica* and *Hymenoclea salsola* were associated with both arroyos and washes. The *Acacia greggii* and *Chilopsis linearis* alliances were the only alliances associated with all topographic positions, but mostly with arroyos.

Variables associated with topographic position sort themselves out in a predictable way. As canyons are mainly erosional features and arroyos and washes are primarily depositional, these positions differ in surface rock cover, elevation, and slope. Canyons have larger surface rock types and coarse to medium-textured soils, while both arroyos and washes have smaller rock types and finer sandy soils. Canyons are at higher elevations, have larger elevation ranges, and have steeper slopes.

These rock, soil, and elevation differences result in available soil moisture and temperature gradients, where canyons may have greater water availability, a greater chance of freezing temperatures, and greater microsite variation. Other studies in North American deserts (Smith et al. 1995, Wondzell et al. 1996, Parker 1988, Parker 1991, Klikoff 1967, Yang and Lowe 1956) show that rocky soils of slopes have higher soil moistures and mesic microsites. These coarser surfaces have more rapid infiltration of water and less evaporation than finer-textured surfaces (Yang and Lowe 1956, Smith et al. 1995, Key et al. 1984). The higher elevation canyons also receive more rainfall because of orographic uplift, and they have decreased insolation, temperature, and evaporation (Barbour and Diaz 1973, Shreve 1924, Thorne et al. 1981). Thus, canyons are cooler, more mesic sites than arroyos and washes, and canyons have more species and alliances associated with them (Tables 7 and 14).

Among and within canyons, vegetation types varied in response to local moisture and temperature differences (Figure 16). Based on aspect, elevation, and surface rock correlations, the *Acacia greggii* and *Chilopsis linearis* associations appear to occupy canyon locations with lower soil moisture and warmer temperatures. On the other hand, the *Quercus turbinella, Q. chrysolepis,* and *Pinus monophylla* alliances probably occupy locations with higher moisture and cooler temperatures. Consequently, these three alliances maintain the highest number and most cover of coniferous trees and broad-leaved large shrubs and trees that are from divergent plant families in western North America.

Some canyon locations have additional water sources from springs and seeps, particularly in granitic bedrock (Cahn and Gibbons 1979, Reneau 1983, Norris and Webb 1990). I observed free-flowing water and pools arising in sections of all four granitic canyons. Wetland species in these canyons include *Carex alma, Eleocharis parishii, Juncus macrophyllus, Juncus mexicanus, Sisyrinchium halophilum,* and *Typha domingensis.* Other species found here, such as *Salix exigua, S. goodingii, Populus fremontii,* and *Prosopis glandulosa,* are phreatophytes that must be in contact with ground water at all times (Smith et al. 1995, Nilsen et al. 1984). Numerous non-native plants are indicator species at these locations, including *Cynodon dactylon, Polypogon monspeliensis, Schismus barbatus, Sonchus oleraceus,* and *Tamarix ramosissima* (Table 18). These species assemblages are similar to those along moist stream borders in the southwestern U.S. deserts where soil water usually is not limited (Brock 1994, Stromberg and Chew 1997).

The moisture and temperature gradients also apply to arroyos and washes, even though they are both shallowly sloping. Due to the higher position of arroyos, they receive more precipitation and lower temperatures than washes. Because arroyos are at the mountain front, they also receive greater water run-off, which effectively infiltrates here (Wondzell et al. 1996). On the other hand, washes have the finest sediments and endure the lowest rainfall, most insolation, the highest temperatures, and the most potential evaporation (Thorne et al. 1981).

Different life-forms of species reflect the moisture and temperature gradients (Appendix E). For example, large deciduous shrubs and trees frequented arroyos more than washes, such as *Acacia greggii, Chilopsis linearis, Prunus fasciculata,* and *Purshia mexicana.* Further, upland species occurred most often in washes. These species can endure high moisture stress and low water potentials, such as *Larrea tridentata* and *Ambrosia dumosa* (Klikoff 1967, Vasek and Barbour 1995). Other species that can endure lower and freezing temperatures are found in higher positions of canyons and arroyos such as *Coleogyne ramosissima* (Lei 1997, Lei and Walker 1997a, Lei and Walker 1997b). Species that can endure a combination of higher temperatures and lower soil moisture are found in lower positions of washes such as *Larrea tridentata* (Beatley 1974a, Vasek and Barbour 1995).

Vegetation types also varied within and among arroyos and washes, attributable to the moisture and temperature gradients (Figure 17). The *Ephedra californica* alliance probably occupies sites with the lowest soil moisture and warmest temperatures while the *Acacia greggii, Encelia virginensis, Chrysothamnus paniculatus,* and *Prunus fasciculata* alliances as well as some *Chilopsis linearis* associations types probably inhabit moister and cooler sites.

Further, the three topographic positions have different disturbance regimes. In canyons disturbance patterns are mostly erosional, unlike arroyos and washes where disturbance patterns are mostly depositional. Large and small rock fragments are eroded and moved along the steeper slopes of canyons, resulting in a highly disturbed environment. A sharp break in slope and relief occurs at the mountain front, in which arroyos and washes have shallow slopes and finer sediments (Wondzell et al. 1996). While depositional processes dominate the shallow arroyo and wash surfaces, significant erosion of coarse rock and sediment can occur in arroyos, especially in arroyos which have high, decomposing alluvial banks or pediment.

These differences in disturbance patterns across the topographic gradient can affect establishment, survival, and patterning of plant species. McHargue (1973) describes washes as highly variable positions with complex patterns of species change due to disturbance and with continual replacement of individuals. He noted a change from *Hymenoclea salsola* and *Bebbia juncea* pioneers to *Acacia greggii* and then to *Chilopsis linearis* and *Psorothamnus spinosus* in Coachella Valley washes after a period lacking disturbance. Further, Jean and Bouchard (1993) found various configurations of vegetation in a riverine wetland depending on the spatial frequency and degree of abiotic disturbance; thus, the diverse vegetation patterning in canyons also may be due to diverse disturbance patterns in space and time.

Difference in geologic substrate

All analyses emphasize the importance of geologic substrate in influencing vegetation patterning. The significant differences in species composition on granite versus limestone may be due to lithologic differences in the amount of surface rock cover, sediment size, nutrient availability, erosion, and soil formation at the local scale.

Canyons of both substrates had a differential mix of coarse and fine rock types (Table 10). Granitic canyons had significantly more fine sediment, boulder, and bedrock while calcareous canyons had more gravel, cobble, and stone. Moisture availability is probably similar in these mixed rock canyons, in which I observed similar species richness and cover of species in canyons on both geologic types (Tables 7 and 8).

On the other hand, granitic arroyos and washes had more fine sediment and fewer large rocks than calcareous sites. These granitic sites may have lower moisture availability whereby granitic arroyos and washes have fewer species and lower ground cover than calcareous arroyos and washes (Table 7 and 8).

Species composition and vegetation types were different in granitic samples as compared to calcareous samples regardless of topographic position (Tables 18 and 21, Figures 9 and 11), probably because species have affinities to particular substrates. The ordination of canyons exhibited a strong geologic gradient along the second ordination axis, and the ordination of arroyos and washes generated this gradient along the first axis.

While both granitic and calcareous substrates have the potential to receive aeolian mineral deposits, these two substrates are considerably different in mineral composition. Wentworth (1981) found that aluminum, iron, and manganese concentrations are lower on limestone (aluminum and iron were below the level of detection for limestone), and calcium, magnesium, and nitrogen macronutrients are higher on limestone. Mean pH of calcareous soils is significantly higher, and these basic soils could result in deficiencies of cations such as iron and cause lime-chlorosis in plants (Wentworth 1981). However, the greater acidity and lower amounts of macronutrients on granite may explain the differences in plant distributions. Kruckeberg (1969) and Raven (1995) suggest that the restriction of plants to calcareous soils may be due to an absence of competition on these variant soils, in which edaphic factors probably contribute to the significant correlation of many species with limestone (Tables 12, 18, and 21).

Rock weathering and erosion rates are also different between the two substrates. Slopes along granite have mobile surfaces, especially along steep slopes above 28°. Granite is sensitive to weathering in arid climates, where grus is eroded from bedrock and boulders and readily carried downslope in rainfall events. Higher slopes have rapid rates of bedrock and boulder breakdown, while lower slopes have less advanced processes (Melton 1965, Bull 1991). Limestone is slightly less sensitive to weathering and movement in arid climates. However, limestone is more sensitive than granite to weathering in semi-arid to humid climates such as in canyons and north-facing slopes (Bull 1991).

Soils differ as well for granitic and calcareous substrates. While calcareous soils are readily permeable to water, they do have a higher probability of forming an indurate layer of calcium carbonate (caliche) that can impede water infiltration and decrease water availability to plants. (McDonald et al. 1995, Rundel and Gibson 1996). In my study, I observed exposed caliche layers in 5 washes with calcareous substrates. These caliche layers may affect species distributions (McAuliffe 1994).

Regional location (phytogeographic considerations)

Both the canyon and arroyo/wash ordinations generated significant correlations for geographic position north and east, which may relate to a regional moisture gradient. The eastern Mojave Desert has more summer precipitation than the western Mojave (see climate section). In addition, northern and eastern sites receive more summer precipitation, less winter precipitation, and lower temperatures, and mountains at these sites attain higher elevations (Tables 1 and 9).

Further, correlations with geographic position may be explained by the varied distributional locations of species. Some species in my study have affinities to montane floras of California, the Great Basin, the Colorado Plateau, and the Rocky Mountains. Most occur in higher elevations and north-facing canyons, such as *Abies concolor, Forestiera pubescens, Fraxinus anomale, Garrya flavescens, Juniperus osteosperma, Quercus chrysolepis, Q. turbinella, Rhamnus ilicifolia, R. tomentella* ssp. *ursina, Pinus monophylla, Salix exigua,* and *Salix goodingii.* They are relictual in the Mojave Desert and experienced range contraction as summer rain and winter temperature decreased (Axelrod 1995).

Salvia dorrii has affinity to arid regions of the Mojave Desert and Great Basin, found on rocky slopes and in canyons and washes (Annable 1985, Hickman 1993). Thus, *Salvia* is found at various positions, particularly canyons and arroyos. Further, *Hymenoclea salsola* and *Ephedra californica* are two lower elevation species that have affinities to arid regions of the southwestern United States, which occur along flats, alluvial fans, and washes (Hickman 1993). McHargue (1973) found that these species are strong constituents in California Sonoran washes, and they rapidly declined with increasing slope and rockiness. Thus, dispersal and lower moisture availability on the fine rock granitic water courses are probably the overriding factors in the patterning of these species.

Other species in the eastern Mojave Desert water courses have centers of distributions in North American Deserts, but they not found in other parts of the Mojave Desert because of lack of summer rain or freezing temperatures in winter. *Chilopsis linearis* is found in higher elevation bajadas and arroyo margins of the Sonoran Desert and Chihuahuan deserts while *Acacia greggii* assumes importance mainly along sandy and rocky washes but also on rocky hillsides of the Sonoran and Chihuahuan deserts (Shreve and Wiggins 1964). *Baccharis sergiloides* is a component of woodland scrub of southern California oases in the Sonoran Desert as well as in cismontane California (Küchler 1995, Hickman 1993). *Psorothamnus spinosus* has affinity to the Sonoran Desert, especially along gravelly, periodically flooded streamways (McHargue 1973, Peinado et al. 1995). Further, *Encelia virginensis* is a small shrub affiliated with the Sonoran Desert along rocky slopes and disturbed flats, and *Chrysothamnus paniculatus* is a medium shrub affiliated with the Great Basin in gravelly washes (Hickman 1993, McHargue 1973).

Relationship to existing classifications

I documented seven established alliances in canyons: *Acacia greggii, Chilopsis linearis, Quercus chrysolepis, Quercus turbinella, Pinus monophylla, Populus fremontii, Salix exigua,* and *Salvia dorrii* (The Nature Conservancy 1999, Sawyer and Keeler-Wolf 1995). Further, I documented four established alliances in arroyos and washes: *Acacia greggii, Chilopsis linearis, Encelia virginensis*, and *Salvia dorrii* alliances (The Nature Conservancy 1999 and Sawyer and Keeler-Wolf 1995). However, I found a lack of published data on the *Baccharis sergiloides, Chrysothamnus paniculatus, Hymenoclea salsola, Ephedra californica, Prunus fasciculata,* and *Psorothamnus spinosus* types.

The *Acacia greggii* and *Pinus monophylla* alliances are well known in the literature for the Mojave Desert and Transverse Ranges (Hart et al. 1979, Sawyer and Keeler-Wolf 1995, Vasek and Barbour 1995, Vasek and Thorne 1995, Thomas et al. 1999). However, I provide evidence for *Acacia greggii/Prunus fasciculata* and *Pinus monophylla-Garrya flavescens* associations in canyons. I also propose five other arroyo and wash associations of the *Acacia greggii* alliance, in which Thomas et al (1999) reports one of these. Hart et al. (1979) describes the *Acacia* greggii/*Prunus fasciculata* association as a common shrubland of the Granite Mountains. Vasek and Thorne (1995) describe woodlands of *Pinus monophylla* that are similar in overstory composition to my association. Further, four other *Pinus monophylla* samples were unclassifiable. In each case *Pinus monophylla* is associated with *Baccharis sergiloides, Prunus fasciculata, Prunus fasciculata* and *Salvia dorrii*, or *Rhamnus ilicifolia* and *Rhamnus tomentella.*

Descriptive data exist for the *Chilopsis linearis* alliance in the Mojave Desert, while I provide evidence for five *Chilopsis linearis* associations. *Chilopsis linearis* and *Acacia greggii* occur as wash woodlands of limited extent in the Kingston Range (Castagnoli et al. 1983), and *Chilopsis linearis* is described as the dominant species in small wash woodlands with *Hymenoclea salsola* in the Granite Mountains (Hart et al. 1979). *Chilopsis* also occurs in washes of heterogeneous wash alluvium in the Coachella Valley (Lang 1977, McHargue 1973) and Anza-Borrego (Keeler-Wolf et al. 1998).

Little data exist for the *Quercus turbinella* alliance in California, and no data exists for the *Salvia dorrii* alliances in California. *Quercus turbinella* is disjunct in the New York Mountains from its more extensive range in the Great Basin and Colorado Plateau (Griffin and Critchfield 1972, Hickman 1993). Data is provided for a *Pinus monophylla* and *Quercus turbinella* mix in the south-facing Caruthers canyon of the New York Mountains (Vasek and Thorne 1995), which is south of my New York canyon site. I recorded *Quercus turbinella* as the principal dominant species in a continuous canyon stand. Existing data for a *Salvia dorrii* alliance is specific to eastern Oregon (The Nature Conservancy 1999) while I provide evidence for this alliance in California.

The *Quercus chrysolepis, Populus fremontii,* and *Salix exigua* occur as localized stands in the eastern Mojave Desert because they are highly restricted environmentally to wet sites. These alliances are extensive in California in more mesic regions (Sawyer and Keeler-Wolf 1995, Sawyer et al. 1995, Küchler 1995). As a phase of pinyon-juniper woodland, a *Quercus chrysolepis* and *Garrya flavescens* association is described for the northern Granite Mountains in upper elevation Bull Canyon (Hart et al. 1979). This association is similar to my proposed *Quercus chrysolepis/Rhamnus ilicifolia* association for Gilroy and Mitchell canyons in the Providence Mountains while I also have observed this association in Winston canyon. Further, *Populus fremontii-Salix exigua/Baccharis sergiloides* and *Populus fremontii/Baccharis sergiloides* are described as rare assemblages at spring and seep sites in the eastern Mojave Desert (Castagnoli et al. 1983, Hart et al. 1979). These compare to my proposed *Populus fremontii/Baccharis sergiloides* and *Salix exigua/Baccharis sergiloides* associations.

I propose two additional canyon alliances, *Baccharis sergiloides* and *Prunus fasciculata*. The *Baccharis sergiloides* alliance is similar to the *Baccharis sarothroides* alliance (The Nature Conservancy 1999, Sawyer and Keeler-Wolf 1995). The *Prunus fasciculata* alliance has been documented recently by Thomas et al. (1999); I propose four new associations occurring in canyons and arroyos.

Some quantitative data exist for the *Chrysothamnus paniculatus, Encelia virginensis, Ephedra californica, Hymenoclea salsola,* and *Prunus fasciculata* shrubland alliances in the Mojave Desert (Thomas et al. 1999). Also, *Ephedra californica* is recorded as the dominant species on rocky bajadas in the Coachella Valley in association with *Bebbia juncea* (McHargue 1973). *Hymenoclea salsola* is described a dominant shrub vegetation type of the Mojave (Hart et al. 1979, Rowlands 1995), and is recorded in large and small washes below the New York and Ivanpah mountains (Housman 1994). *Hymenoclea salsola* is also documented as the most important species of Coachella Valley sandy washes in the Sonoran Desert of California (McHargue 1973, Lang 1977).

Further, I recognize *Psorothamnus spinosus* as a shrubland alliance from the two southernmost samples. This type is similar to the Sonoran Desert *Cercidium floridum-Olneya tesota-Psorothamnus spinosus* series of Sawyer and Keeler-Wolf (1995). A few samples of a *Psorothamnus spinosus* shrubland alliance are recorded in the southern Mojave Desert (Thomas et al. 1999). Quantitative data also exists in the Sonoran Desert for *Psorothamnus* as an association with *Hymenoclea salsola* in Baja, California (Peinado et al. 1995), and as a dominant woodland association in Anza-Borrego, California (Spolsky 1979, Keeler-Wolf et al. 1998).

CONCLUSIONS

As the eastern Mojave Desert has a complex overlay of topography and substrate, watercourse vegetation diversely varies as gradients in the environment are crossed. Spatial variations in moisture, temperature, and geology appear to effect vegetation patterning at different scales. At the local scale, moisture and temperature are controlled by the topographic gradient through aspect, elevation, and topographic position. The topographic gradient and its consequent changes of environmental parameters are broadly expressed in the vegetation patterning. At the regional scale, moisture and temperature are controlled by dominant geographic weather patterns. At a more local scale, when geologic substrate is superimposed on the topographic gradient and geographic patterns, a mosaic of different environments result. These environments vary in moisture availability, nutrient availability, and rock weathering/soil formation.

Vegetation occurring in granitic and calcareous water courses in the eastern Mojave Desert, California, can be classified in terms of at least 15 alliances and 32 associations. Alliances found in wetter, cooler water courses such as canyons include forests of *Quercus chrysolepis*, temporarily flooded woodlands of *Populus fremontii*, woodlands of *Pinus monophylla*, intermittently flooded shrublands of *Baccharis sergiloides*, temporarily flooded shrublands of *Salix exigua*, and shrublands of *Prunus fasciculata*, *Quercus turbinella*, and *Salvia dorrii*. Alliances found in drier, warmer water courses such as arroyos and washes are shrublands of *Chrysothamnus paniculatus*, *Encelia virginensis*, *Ephedra californica*, *Hymenoclea salsola*, *Prunus fasciculata*, *Psorothamnus spinosus,* and *Salvia dorrii.* Alliances found across the topographic positions are shrublands of *Acacia greggii* and intermittently flooded shrublands of *Chilopsis linearis.*

Alliances found particularly on granite are *Baccharis sergiloides*, *Ephedra californica*, *Hymenoclea salsola*, *Populus fremontii, Psorothamnus spinosus, Quercus turbinella,* and *Salix exigua*, while on limestone are *Encelia virginensis* and *Salvia dorrii.* The other six alliances are found on both substrates. Eleven associations have an affinity to granitic substrate. Fourteen are principally on calcareous substrate, including four *Acacia greggii,* five *Chilopsis linearis*, and three *Prunus fasciculata* associations.

In my fine-scale study, I established four alliances, *Baccharis sergiloides, Chilopsis linearis, Quercus turbinella,* and *Salvia dorrii*, which are not recognized by Sawyer and Keeler-Wolf (1995) and Thomas et al (1999) with at least three replicate samples. I also documented an association of *Pinus monophylla-Garrya flavescens*, *Salix exigua/Baccharis sergiloides,* and *Quercus chrysolepis/Rhamnus ilicifolia,* and several *Acacia greggii* and *Prunus fasciculata* associations not recognized by published sources.

Further, numerous water course vegetation types and species documented in this study such as *Populus fremontii, Psorothamnus spinosus, Quercus chrysolepis, Quercus turbinella,* and *Salix exigua* are limited in distribution in the Mojave Desert because of environmental constraints. As a variety of common and rare vegetation assemblages occur in water courses along a topographic gradient, conservation and management of biodiversity may be fostered effectively by this knowledge of water course vegetation types and of environmental factors that influence vegetation patterns.

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Appendix A. Species list of plants used in analyses for the eight water courses of the eastern Mojave Desert. Codes to the left of the scientific names are * for non-native, and 1B, 2, and 4 for the California Native Plant Society's listing of rare and endangered plants (California Department of Fish and Game 1999).

Dryopteridaceae

Woodsia oregane D. Eaton

Pteridaceae

Argyrochosma jonesii (Maxon) M.D. Windham
Cheilanthes covillei Maxon
Cheilanthes feei T. Moore
Cheilanthes viscida Davenp.
Pellaea mucronata (D. Eaton) D. Eaton

Ephedraceae

Ephedra californica S. Watson
Ephedra fasciculata Nelson
Ephedra nevadensis S. Watson
Ephedra viridis Cov.

Cupressaceae

Juniperus osteosperma (Torrey) Little

Pinaceae

Abies concolor (Gordon & Glend) Lindey
Pinus monophylla Torrey & Fremont

Anacardiaceae

Rhus trilobata Torrey & A. Gray

Apiaceae

Lomatium parryi (S. Watson) J.F. Macbr.

Asclepiadaceae

Asclepias asperula (Decne.) Woodson ssp. *asperula*
Asclepias erosa Torrey
Sarcostemma hirtellum (A. Gray) R. Holm

Appendix A. Continued

Asteraceae

Acamptopappus shockleyi A. Gray
Acamptopappus sphaerocephalus (A. Gray) A. Gray
Adenophyllum cooperi (A. Gray) Strother
Adenophyllum porophylloides (A. Gray) Strother
Ageratina herbacea (A. Gray) R. King & H. Robinson
Ambrosia dumosa (A. Gray) Payne
Ambrosia eriocentra (A. Gray) Payne
Artemisia ludoviciana Nutt.
Artemisia bigelovii A. Gray
Artemisia dracunculus L.
Artemisia nova Nelson
Artemisia tridentata Nutt.
Baccharis salicifolia (Ruiz Lopez & Pavon) Pers.
Baccharis sergiloides A. Gray
Bebbia juncea (Benth.) E. Greene var. *aspera* E. Greene
Brickellia arguta Robinson
Brickellia californica (Torrey & A. Gray) A. Gray
Brickellia desertorum Cov.
Brickellia incana A. Gray
Brickellia knappiana Drew
Brickellia multiflora Kellogg
Brickellia oblongifolia Nutt var. *linifolia* (D. Eaton) Robinson
Brickellia watsonii Robinson
Chyrsothamnus depressus Nutt.
Chrysothamnus nauseosus (Pallas) Britton
Chrysothamnus paniculatus (A. Gray) H.M. Hall
Chrysothamnus teretifolius (Durand & Hilg.) H.M. Hall
Cirsium neomexicanum A. Gray
Encelia farinosa Torrey & A. Gary
Encelia actoni Elmer[1]
Encelia frutescens (A. Gray) A. Gray
Encelia virginensis Nelson[2]
Erigeron concinnus (Hook. & Arn.) Torrey & A. Gray var. *concinnus*
Ericameria cuneata (A. Gray) McClatchie var. *spathulata* (A. Gray) H.M. Hall

[1] *Encelia actoni* in the analyses is not distinguished from *E. virginensis*
[2] *Encelia virginensis* in the analyses is not distinguished from *E. actoni*

Appendix A. Continued

Ericameria laricifolia (A. Gray) G. Nesom[3]
Ericameria linearifolia (DC.) Urb & J. Wussow[4]
Erigeron divergensTorrey & A. Gray
Erigeron utahensis A. Gray
Gutierrezia microcephalus (DC.) A. Gray
Gutierrezia sarothrae (Pursh) Brotton & Rusby
Heliomeris multiflora Nutt. var. *nevadensis* (Nelson) Yates
Hymenoclea salsola A. Gray
Hymenoxys cooperi (A. Gray) Cockerell
Petradoria pumila (Nutt.) E. Greene ssp. *pumila*
Pleurocoronis pluriseta (A. Gray) R. King & H. Robinson
Porophyllum gracile Benth.
Psilostrophe cooperi (A. Gray) E. Greene
Senecio flaccidus Less var. *monoensis* (E. Greene) B.Turner& T. Barkley
Sonchus oleraceus L.
Solidago confinis Nutt.
Stephanomeria pauciflora (Nutt.) Nelson
4 *Tetradymia argyraea* Munz & Roos
Tetradymia stenolepis E. Greene
Viguiera parishii E. Greene
Xylorhiza tortifolia (Torrey & A. Gray) E. Greene var. *tortifolia*

Bignoniaceae
Chilopsis linearis (Cav.) Sweet ssp. *arcuata* (Fosb.) Henrickson

Boraginaceae
Cryptantha flavoculata (Nelson) Payson
4 *Cryptantha tumulosa* (Payson) Pason
Cryptantha virginensis (M.E. Jones) Payson
Tiquilia canescens (DC.) A. Richardson

Brassicaceae
Arabis perennans S. Watson
Arabis pulchra M.E. Jones
Lepidium fremonti S. Watson
Physaria chambersii Rollins
* *Sisymbrium orientale* L.

[3] *Ericameria laricifolia* is not distinguished from *E. linearifolia*
[4] *Ericameria linearifolia* is not distinguished from *E. laricifolia*

Stanleya pinnata (Prush) Britton var. *pinnata*

Cactaceae

Echinocereus engelmannii (Engelm.) Lemaire
Echinocactus polycephalus Engelm. & J. Bigelow var. *polycephalus*
Echinocereus triglochidiatus Engelm.
Escobaria vivipara (Nutt.) F. Buxb.var. *deserti* (Engelm.) D. Hunt
Ferocactus cylindraceus (Engelm.) Orc.
Opuntia acanthocarpa Engelm. & J. Bigelow var. *coloradensis* L. Benson
Opuntia basilaris Engelm. & J. Bigelow var. *basilaris*
Opuntia chlorotica Engelm. & J. Bigelow
Opuntia echinocarpa Engelm. & J. Bigelow
Opuntia erinacea Engelm. & J. Bigelow var. *erinacea*
Opuntia parishii Orc.
Opuntia ramosissima Engelm.

Capparaceae

Isomeris arborea Nutt.

Caprifoliaceae

Sambucus mexicana C. Presl
Symphoricarpos longiflorus A. Gray

Caryophyllaceae

Arenaria macradenia S. Watson var. *macradenia*
Silene verecunda ssp. andersonii

Chenopodiaceae

Atriplex canescens (Prush) Nutt. ssp *canescens*

Crassulaceae

Dudleya pulverulenta (Nutt.) Britton & Rose ssp. *arizonica* (Rose) Moran
Dudleya saxosa (M.E. Jones) Britton & Rose ssp. *aloides* (Rose) Moran

Crossosomataceae

Glossopetalon spinescens A. Gray

Cucurbitaceae

Cucurbita palmata S. Watson

Appendix A. Continued

Euphorbiaceae

Chamaesyce albomarginata (Torrey & A. Gray) Small
Euphorbia incisa Engelm.
Stillingia linearifolia S. Watson
Tragia ramosa Torrey

Fabaceae

Acacia greggii A. Gray
Astragalus lentiginosus Hook. var. *fremontii* (A. Gray) S. Watson
Astragalus mojavensis S. Watson var. *mojavensis*
4 *Astragalus nutans* M.E. Jones
Lotus rigidus (Benth.) E. Greene
Prosopis glandulosa Torrey var. *torreyana* (L. Benson) M. Johnston
Psorothamnus arborescens (A. Gray) Barneby var. *minutifolius* (Parish) Barneby
Psorothamnus spinosus (A. Gray) Barneby
Senna armata (S. Watson) H. Irwin & Barneby

Fagaceae

Quercus chrysolepis Liebm.
Quercus turbinella E. Greene

Garryaceae

Garrya flavescens S. Watson

Geraniaceae

* *Erodium cicutarium* (L.) L'Her.

Grossulariaceae

Ribes velutinum E. Greene

Krameriaceae

Krameria erecta Schultes
Krameria grayi Rose & Painter

Lamiaceae

Hedeoma nanum (Torrey) Briq. var. *californicum* W.S. Stewart
Monardella linoides A. Gray ssp. *linioides*
Salazaria mexicana Torrey
Salvia dorrii (Kellogg) Abrams

Salvia mohavensis E. Greene
Salvia pachyphylla Munz

Lennoaceae
Pholisma arenarium Hook.

Loasaceae
Petalonyx thurberi A. Gray ssp. *thurberi*

Malvaceae
Sphaeralcea ambigua A. Gray var.

Nyctaginaceae
Allionia incarnata L.
Mirabilis bigelovii A. Gray var. *retrorsa* (A.A. Heller) Munz
Mirabilis coccinea (Torrey) Benth & Hook.
Mirabilis multiflora (Torrey) A. Gray var. *pubescens* S. Watson
Mirabilis oblongifolia (A. Gray) Heimerl
Mirabilis pumila (Standley) Standley

Oleaceae
Forestiera pubescens Nutt.
Fraxinus anomale S. Watson
Menodora scoparia A. Gray
Menodora spinescens A. Gray

Onagraceae
Epilobium canum (E. Greene) Raven ssp. *canum*
Gaura coccinea Prush.
Oenothera cespitosa Nutt. ssp. *marginata* (Hook. & Arn.) Munz
Oenothera primiveris A. Gray ssp. *primiveris*

Orobanchaceae
Orobanche cooperi (A. Gray) A.A. Heller
Orobanche fasciculata Nutt.

Papaveraceae
Argemone munita Durand & Hilg.

Appendix A. Continued

Philadelphaceae
4 *Fendlerella utahensis* (S. Watson) A.A. Heller
Philadelphus microphyllus A. Gray

Polemoniaceae
Leptodactylon pungens (Torrey) Rydb.
Phlox stansburyi (Torrey) A.A. Heller

Polygonaceae
Eriogonum fasciculatum Benth. var. polifolium (A. DC) Torrey & A. Gray
4 *Eriogonum heermanii* Durand & Hilg. var *floccosum* Munz[5]
Eriogonum heermanii Durand & Hilg. var *sulcatum* (S. Watson) Munz & Rev[6]
Eriogonum inflatum Torrey & Fremont var. *deflatum* I.M. Johnson
Eriogonum microthecum Nutt. var. *simpsonii* (A. DC.) Rev.
Eriogonum panamintense C. Morton
Eriogonum plumatella Durand & Hilg.
Eriogonum umbellatum Torrey
Eriogonum wrightii Benth var. *wrightii*

Ranunculaceae
Anemone tuberosa Rydb.

Rhamnaceae
Rhamnus ilicifolia Kellogg
Rhamnus tomentella Benth.

Rosaceae
Amelanchier utahensis Koehne
Cercocarpus intricatus S. Watson
Coleogyne ramosissima Torrey
Fallugia paradoxa (D. Don) Endl.
Holodiscus microphyllus Rydb. var. *microphyllus*
Petrophyton caespitosum (Nutt.) Rydb. ssp. *caespitosum*
Prunus fasciculata (Torrey) A. Gray var. *fasiculata*
Purshia mexicana (D. Don) Welsh var. *stansburyana* (Torrey) Welsh
Purshia tridentata (Pursh) DC var. *glandulosa* (Curran) M.E. Jones

[5] *Eriogonum heermanii* ssp. *flocossum* in the analyses is not distinguished from *E. h. sulcatum*
[6] *Eriogonum heermanii* spp. *sulcatum* in the analyses is not distinguished from *E. h. flocossum*

Rubiaceae
4 *Galium angustifolium* Nutt. Ssp. *gracillimum* Dempster & Stebb.
4 *Galium munzii* Hilend & J. Howell
Galium parishii Hilend & J. Howell
Galium stellatum Kellogg var. *eremicum* Hilend & J. Howell

Rutaceae
Thamnosma montana Torrey & Fremont

Salicaceae
Populus fremontii S. Watson ssp. *fremontii*
Salix exigua Nutt.
Salix gooddingii C. Ball

Saxifragaceae
Heuchera rubescens Torrey var. *alpicola* Jepson

Scrophulariaceae
Castilleja angustifolia (Nutt.) G. Don
Castilleja linariifolia Benth.
Keckiella antirrhinoides (Benth) Straw var. *microphylla* (A. Gray) N. Holmgren
2 *Maurandya antirrhiniflora* Willd. ssp. *antirrhiniflora*
Penstemon eatonii A. Gray
Penstemon palmeri A. Gray var. *palmeri*
Penstemon rostiflorus Kellogg
1B *Penstemon stephensii* Brandegee

Solanaceae
Datura wrightii Regel
Lycium andersonii A. Gray
Lycium cooperi A. Gray
Nicotiana obtusifolia Martens & Galeotti
Physalis crassifolia Benth.
Physalis hederifolia A. Gray

Tamaricaceae
* *Tamarix ramosissima* Ledeb.

Appendix A. Continued

Verbenaceae

Aloysia wrightii Abrams

Viscaceae

Phoradendron californica Nutt.
Phoradendron juniperum A. Gray

Zygophyllaceae

Larrea tridentata (DC.) Cov.

Cyperaceae

Eleocharis parishii Britton
Carex alma L. Bailey

Iridaceae

Sisyrinchium halophilum E. Greene

Juncaceae

Juncus macrophyllus Cov.
Juncus mexicanus Willd.

Liliaceae

Agave deserti (Engelm.) Gentry
4 *Agave utahensis* (Engelm.) Gentry
Yucca baccata Torrey
Yucca brevifolia Engelm.
Yucca schidigera K.E. Ortgies

Poaceae

Achnatherum hymenoides (Roemer & Schultes) Barkworth
Achnatherum parishii (Vasey) Barkworth
Achnatherum speciosum (Trin. & Rupr.) Barkworth
* *Agrostis viridis* Gouan
Aristida purpurea Nutt.
* *Avena fatua* L.
Bothriocloa barbinodis (Lasaca) Herter
Bouteloua curtipendula (Michaux) Torrey
Bouteloua gracilis (Kunth) Griffiths
* *Bromus diandrus* Roth

Appendix A. Continued

* *Bromus madritensis* L. ssp. *rubens* (L.) Husnot
* *Bromus tectorum* L.
* *Bromus trinii* Desv.
Elymus elymoides (Raf.) Swezey ssp. *breviflorus* (J.G. Smith) Barkworth[7]
Elymus elymoides (Raf.) Swezey ssp. *elymoides*[8]
* *Cynodon dactylon* (L.) Pres.
Erioneuron pulchellum (Kunth) Takeoka
Leymus salinus (M.E. Jones) A. Love ssp. *mojavensis* Barkworth & R.J. Atkins
Melica frutescens Scribnner
Melica imperfecta Trin.
Muhlenbergia porteri Beal
Muhlenbergia rigens (Benth.) A. Hitchc.
Phragmites australis (Cav.) Steudel
Pleuraphis rigida Thurber
Poa fendleriana (Steudel) Vasey ssp. *longiligula*
Poa secunda ssp. J.S. Presl
* *Polypogon monspeliensis* (L.) Desf.
* *Schismus barbatus* (l.) Thell.
Sporobolus cryptandrus (Torrey) A. Gray
Tridens muticus (Torrey) Nash

Typhaceae
Typha domingensis Pers.

[7] *Elymus elymoides* ssp. *breviflorus* in the analyses is not distinguished from *E. e. elymoides*
[8] *Elymus elymoides* spp. *elymoides* in the analyses is not distinguished from *E. e. breviflorus*

Appendix B. Cross-reference of datasets and species codes used in the analyses to scientific and common names of species (Hickman 1993, Jaeger 1969). Dataset codes are ✱ for the complete data analyses, ● for the canyon data analyses, and + for the wash/arroyo data analysis. See Appendix A for complete taxonomic nomenclature.

Dataset Code	Species Code	Scientific name	Common name
	abco	*Abies concolor*	Rocky Mountain white fir
✱●+	acgr	*Acacia greggii*	catclaw acacia
	achy	*Achnatherum hymenoides*	ricegrass, sand bunchgrass
●	acpa	*Achnatherum parishii*	
	acsh	*Acamptopappus shockleyi*	Shockley goldenhead
●	acsp	*Acamptopappus sphaerocephalus*	goldenhead
✱●+	acsp1	*Achnatherum speciosum*	desert needlegrass, speargrass
✱+	adco	*Adenophyllum cooperi*	Cooper dyssodia, Cooper dogweed
	adpo	*Adenophyllum porophylloides*	San Felipe dyssodia
●	agde	*Agave deserti*	desert agave, century plant
●	agheg	*Ageratina herbacea*	
●	agutg	*Agave utahensis*	Utah agave, pygmy agave
●	agvi	*Agrostis viridis*	bent grass
✱+	alin	*Allionia incarnata*	windmills
	alwr	*Aloysia wrightii*	oreganillo
✱+	amdu2	*Ambrosia dumosa*	white bursage, burrobush
✱●+	amer	*Ambrosia eriocentra*	woolly bursage
	amut	*Amelanchier utahensis*	Utah serviceberry
	antu	*Anemone tuberosa*	desert windflower
	arbi	*Artemisia bigelovii*	Bigelow sagebrush
●	ardr	*Artemisia dracunculus*	tarragon
●	arjo2	*Argyrochosma jonesii*	Jones cloak fern
✱●	arlu	*Artemisia ludoviciana*	white-sage, pinyon wormwood
●	arma3	*Arenaria macradenia*	desert sandwort
	armu	*Argemone munita*	prickly poppy
	arno4	*Artemisia nova*	black sagebrush
●	arpe2	*Arabis perennans*	
	arpu2	*Arabis pulchra*	prince's rock-cress
✱●+	arpu9	*Aristida purpurea*	three-awn
●	artr2g	*Artemisia tridentata*	Great Basin sagebrush, big sagebush
●	asasa	*Asclepias asperula*	antelope horns
	aser2	*Asclepias erosa*	desert milkweed

Appendix B. Continued

Dataset Code	Species Code	Scientific name	Common name
*●	aslef	*Astragalus lentiginosus*	freckled milkvetch
●	asmo5	*Astragalus mojavensis*	Mojave locoweed
●	asnu3	*Astragalus nutans*	lax-flowered locoweed
	atca2	*Atriplex canescens*	four-wing saltbush, hoary saltbush
	avfa	*Avena fatua*	wild-oat
	basa4	*Baccharis salicifolia*	seep-willow, mule-fat, water-wally
*●+	base	*Baccharis sergiloides*	desert baccharis, waterweed, saratoga
*●+	bejua	*Bebbia juncea*	Chuckwalla's delight, sweet-bush
●	boba	*Bothriocloa barbinodis*	cane bluestem
●	bocu	*Bouteloua curtipendula*	side-oats grama
	bogr	*Bouteloua gracilis*	blue grama grass
	brar2	*Brickellia arguta*	California spearleaf brickellbush
*●	brca3	*Brickellia californica*	California brickellia or brickellbush
	brde3	*Brickellia desertorum*	desert brickellbush
*●	brdi	*Bromus diandrus*	ripgut grass
*+	brin	*Brickellia incana*	white or woolly brickellbush
	brkn	*Brickellia knappiana*	Knapp's or willow brickellbush
*●	brlom	*Brickellia multiflora*	Inyo or gumleaf brickellbush
*●+	brma3	*Bromus madritensis*	foxtail chess
	brmiw	*Brickellia watsonii*	sweet brickellbush
●	brobl	*Brickellia oblongifolia*	pinyon or narrowleaf brickellbush
*●+	brte	*Bromus tectorum*	cheat grass, downy brome
●	brtr	*Bromus trinii*	Chilean chess
●	caal	*Carex alma*	sedge
*●+	caan7	*Castilleja angustifolia*	desert paintbrush
*●	cali4	*Castilleja linariifolia*	long-leaved paintbrush
●	cein7	*Cercocarpus intricatus*	little-leaf mahogany
*+	chal11	*Chamaesyce albomarginata*	rattlesnake or white margined spurge
	chco	*Cheilanthes covillei*	bread fern, lip fern
●	chde	*Chyrsothamnus depressus*	
●	chfe	*Cheilanthes feei*	slender lip fern
*●+	chlia	*Chilopsis linearis*	desert-willow, desert catalpa
●	chnan	*Chrysothamnus nauseosus*	golden or rubber rabbitbrush
*+	chpa	*Chrysothamnus paniculatus*	black-banded or sticky rabbitbrush
	chte	*Chrysothamnus teretifolius*	needleleaf rabbitbrush
	chvi2	*Cheilanthes viscida*	viscid lip fern

Appendix B. Continued

Dataset Code	Species Code	Scientific name	Common name
*●+	cine	*Cirsium neomexicanum*	desert or New Mexico thistle
*●	cora	*Coleogyne ramosissima*	blackbush
●	crfl	*Cryptantha flavoculata*	sulfur-throat forget-me-not
	crtu	*Cryptantha tumulosa*	
*●+	crust	*Cryptogamic crust*	
	crvi5	*Cryptantha virginensis*	tufted forget-me-not
+	cupa	*Cucurbita palmata*	coyote gourd or coyote melon
●	cyda	*Cynodon dactylon*	bermuda grass
*●+	dawr2	*Datura wrightii*	jimson weed, thorn-apple
●	dupua2	*Dudleya pulverulenta*	Arizona live-forever
●	dusa	*Dudleya saxosa*	live-forever
*●+	ecen	*Echinocereus engelmannii*	Engelmann's hedgehog cactus
	ecpo	*Echinocactus polycephalus*	cottontop cactus
*●	ectr	*Echinocereus triglochidiatus*	Mojave mound cactus
*●	elele	*Elymus elymoides*	squirreltail
●	elpa	*Eleocharis parishii*	spikerush
+	enfa	*Encelia farinosa*	brittlebush
	enfr	*Encelia frutescens*	rayless encelia
*●+	enva	*Encelia virginensis/actoni*	Virgin River encelia, Acton encelia
*+	epca2	*Ephedra californica*	California joint-fir, mormon tea
●	epca3	*Epilobium canum*	California fucsia, zauschneria
	epfac	*Ephedra fasciculata*	
*●+	epne	*Ephedra nevadensis*	Nevada joint-fir
*●+	epvi	*Ephedra viridis*	mountain joint-fir
*●+	erci6	*Erodium cicutarium*	filaree, stork's bill
●	ercol	*Erigeron concinnus*	tidy fleabane
*●	ercus	*Ericameria cuneata*	rock or wedgeleaf goldenbush
●	erdi	*Erigeron divergens*	fleabane, wild daisy
*●	erfa2	*Eriogonum fasciculatum*	California-buckwheat
*●	erhes	*Eriogonum heermanii*	Heermann buckwheat
*●	erin4	*Eriogonum inflatum*	desert trumpet, bladderstem
*●	erli6	*Ericameria linearifolia*	interior or linear-leaved goldenbush
●	ermi	*Eriogonum microthecum*	Great Basin buckwheat
	erpa	*Eriogonum panamintense*	Panamint buckwheat
*+	erpl3	*Eriogonum plumatella*	flat-top, plume buckwheat
*●+	erpu8	*Erioneuron pulchellum*	fluff grass

Appendix B. Continued

Dataset Code	Species Code	Scientific name	Common name
	erum	*Eriogonum umbellatum*	sulfur flower
●	erut	*Erigeron utahensis*	Utah fleabane
*●	erwr	*Eriogonum wrightii*	Wright buckwheat
*●+	esvid	*Escobaria vivipara*	pincushion cactus
*●	euin2	*Euphorbia incisa*	Mojave spurge
	f_ast	*F-Asteraceae*	unidentified perennial aster
	f_poa	*F-Poaceae*	unidentified perennial grass
*●+	fapa	*Fallugia paradoxa*	Apache plume, ponil
*●+	fecy	*Ferocactus cylindraceus*	California barrel cactus
	feutg	*Fendlerella utahensis*	yerba desierto
	fopu	*Forestiera pubescens*	desert olive, tangleberry
●	fran	*Fraxinus anomale*	single-leaf ash
*●	gaan2	*Galium angustifolium*	narrow-leaved or slender bedstraw
*●+	gaco5	*Gaura coccinea*	wild-honeysuckle, Linda tarde
*●	gafl	*Garrya flavescens*	yellow-leaf silktassel
*●	gamu	*Galium munzii*	Munz's bedstraw
*●	gapa4	*Galium parishii*	Parish's bedstraw
	gaste3	*Galium stellatum*	desert bedstraw
	glsp	*Glossopetalon spinescens*	Nevada greasewood
*●+	gumi	*Gutierrezia microcephalus*	sticky snakeweed, rosin weed
*●+	gusa2	*Gutierrezia sarothrae*	broom snakeweed, matchweed
●	hemun	*Heliomeris multiflora*	golden-eye
*●	henac	*Hedeoma nanum*	mock pennyroyal
●	heru	*Heuchera rubescens*	alumroot
	homi	*Holodiscus microphyllus*	shrubby creambush
●	hyco	*Hymenoxys cooperi*	biennial goldflower
*●+	hysa	*Hymenoclea salsola*	cheesebush, burrobush
*+	isar	*Isomeris arborea*	bladderpod
*●	juma	*Juncus macrophyllus*	
●	jume4	*Juncus mexicanus*	Mexican rush
*●	juos	*Juniperus osteosperma*	Utah juniper
*●	keanm	*Keckiella antirrhinoides*	littleleaf bush penstemon
*●+	krer	*Krameria erecta*	Range, pima, or little-leaved ratany
*+	krgr	*Krameria grayi*	White ratany
*●+	latr	*Larrea tridentata*	Creosote bush, greasewood
*+	lefrf	*Lepidium fremonti*	Shrubby peppercress, desert alyssium

Appendix B. Continued

Dataset Code	Species Code	Scientific name	Common name
●	lepu	*Leptodactylon pungens*	granite-gilia, prickly-phlox
●	lesam	*Leymus salinus*	
*●	lichen	*Lichen*	
●	lopa	*Lomatium parryi*	Parry biscuitroot, wild parsley
●+	lori3	*Lotus rigidus*	desert rock-pea, desert deerweed
*●+	lyan	*Lycium andersonii*	Anderson lycium, desert thorn
+	lyco2	*Lycium cooperi*	Cooper lycium, peachthorn, boxthorn
●	maana	*Maurandya antirrhiniflora*	violet twining snapdragon
●	mefr	*Melica frutescens*	tall melic
	meim	*Melica imperfecta*	small-flowered melic
●	mesc2	*Menodora scoparia*	
+	mesp2	*Menodora spinescens*	spiny menodora, twinfruit
*●+	mibi8	*Mirabilis bigelovii*	wishbone bush
	mico	*Mirabilis coccinea*	red umbrella-wort
*●+	mimup	*Mirabilis multiflora*	giant four o'clock
	miob	*Mirabilis oblongifolia*	
*●+	mipu6	*Mirabilis pumila*	little umbrella-wort
●	moli3	*Monardella linoides*	flax-leaf pennyroyal
*●+	moss	*Moss*	
*+	mupo2	*Muhlenbergia porteri*	Bush muhly
*●	muri2	*Muhlenbergia rigens*	deergrass
*●+	niob	*Nicotiana obtusifolia*	desert tobacco
*●+	oece2	*Oenothera cespitosa*	desert or tufted evening primrose
●	oepr	*Oenothera primiveris*	
*●+	opapcc	*Opuntia acanthocarpa*	buckhorn or cane cholla
*●+	opba2	*Opuntia basilaris*	beavertail cactus
●	opch	*Opuntia chlorotica*	pancake prickly pear
*+	opec	*Opuntia echinocarpa*	silver cholla
*●+	oper	*Opuntia erinacea*	old man or granddaddy cactus
	oppa	*Opuntia parishii*	mat or club cholla, dead cactus
*●+	opph	*Opuntia phaeacantha*	
*+	opra	*Opuntia ramosissima*	pencil cholla, diamond cholla
+	orco4	*Orobanche cooperi*	burroweed strangler
	orfa	*Orobanche fasciculata*	clustered broom-rape
	peca	*Petrophyton caespitosum*	rock spiraea
●	peea	*Penstemon eatonii*	Eaton firecracker penstemon

Appendix B. Continued

Dataset Code	Species Code	Scientific name	Common name
●	pemu	*Pellaea mucronata*	bird's-foot fern
*●+	pepap	*Penstemon palmeri*	Palmer or scented penstemon
	pepup	*Petradoria pumila*	rock goldenrod
	perog	*Penstemon rostiflorus*	
●	pest	*Penstemon stephensii*	Stephens' beardtongue
+	peth4	*Petalonyx thurberi*	sandpaper plant
*+	phar5	*Pholisma arenarium*	sand food, scaley-stemmed sand plant
	phau	*Phragmites australis*	common reed
*● +	phca8	*Phoradendron californi*	desert mistletoe
	phch	*Physaria chambersii*	double bladderpod
*●+	phcr1	*Physalis crassifolia*	thick-leaved ground cherry
*●+	phhe4	*Physalis hederifolia*	ivy-leaved ground cherry
	phju	*Phoradendron juniperum*	Juniper mistletoe
	phmi4	*Philadelphus microphyllus*	littleleaf mock orange
●	phst	*Phlox stansburyi*	long-leaf phlox
*●	pimo	*Pinus monophylla*	Single-leaf pinyon pine
	plpl	*Pleurocoronis pluriseta*	arrowleaf
+	plri3	*Pleuraphis rigida*	big galleta grass
*●	pofel	*Poa fendleriana*	longtongue mutton grass
	pofrf	*Populus fremontii*	Fremont cottonwood
+	pogr5	*Porophyllum gracile*	odora
●	pomo	*Polypogon monspeliensis*	annual beard grass
●	pose	*Poa secunda*	one-sided bluegrass
*●+	prfa	*Prunus fasciculata*	desert almond, wild almond
●	prglt	*Prosopis glandulosa*	Honey mesquite
*+	psarm	*Psorothamnus arborescens*	Mojave dalea or indigo bush
*+	psco2g	*Psilostrophe cooperi*	whitestem paperflower
	pssp3	*Psorothamnus spinosus*	smoke tree
*●	pume	*Purshia mexicana*	cliff-rose, quinine bush
*●	putr2	*Purshia tridentata*	antelopebush, buckbrush, bitterbrush
●	quch2	*Quercus chrysolepis*	canyon live oak, gold-cup live oak
*●	qutu	*Quercus turbinella*	desert scrub oak, Turbinella live oak
*●	rhcri	*Rhamnus ilicifolia*	holly-leaf redberry
●	rhtou	*Rhamnus tomentella*	hoary coffeeberry
*●+	rhtr	*Rhus trilobata*	skunkbrush
●	rive	*Ribes velutinum*	plateau gooseberry

Appendix B. Continued

Dataset Code	Species Code	Scientific name	Common name
*●+	sado4	*Salvia dorrii*	desert purple sage
●	saex	*Salix exigua*	sand bar or narrow-leaved willow
	sago	*Salix gooddingii*	Goodding's black willow
	sahi2	*Sarcostemma hirtellum*	trailing townula, rambling milkweed
*●+	same1	*Salazaria mexicana*	Mexican bladder-sage, paperbag bush
	same2	*Sambucus mexicana*	blue or southwestern elderberry
*●	samo3	*Salvia mohavensis*	Mojave sage
	sapa	*Salvia pachyphylla*	rose sage
*●+	scba	*Schismus barbatus*	Mediterranean grass
*+	sear8	*Senna armata*	desert cassia, desert senna
*●+	seflm	*Senecio flaccidus*	sandwash or threadleaf groundsel
●	siha	*Sisyrinchium halophilum*	blue-eyed-grass
	sior	*Sisymbrium orientale*	
●	sivea	*Silene verecunda*	
*●	sool	*Sonchus oleraceus*	common sow-thistle
	sospcg	*Solidago confinis*	southern goldenrod
*●+	spam2	*Sphaeralcea ambigua*	desert globe mallow, desert-hollyhock
●	spcr	*Sporobolus cryptandrus*	sand dropseed
+	stli3	*Stillingia linearifolia*	toothleaf
*●+	stpa4	*Stephanomeria pauciflora*	wire-lettuce, desert-straw
	stpi	*Stanleya pinnata*	desert prince's plume
●	sylo	*Symphoricarpos longiflorus*	fragrant snowberry
*●	tara	*Tamarix ramosissima*	salt-cedar, tamarisk
	tear	*Tetradymia argyraea*	striped horsebush
	tests	*Tetradymia stenolepis*	Mojave horsebush, cotton-thorn
*●+	thmo	*Thamnosma montana*	Turpentine broom
	tica3	*Tiquilia canescens*	
*●+	trmu	*Tridens muticus*	slim tridens, awnless tridens
*●	trra5	*Tragia ramosa*	tragia
●	tydo	*Typha domingensis*	southern cattail
*●+	vipar	*Viguiera parishii*	desert goldeneye
●	woor	*Woodsia oregane*	cliff fern
	xytot	*Xylorhiza tortifolia*	Mojave aster, desert aster
*●+	yuba	*Yucca baccata*	banana yucca
*+	yubr	*Yucca brevifolia*	Joshua tree
*●+	yusc2	*Yucca schidigera*	Mojave yucca

Appendix C. Codes defining the sample characteristics of the environmental dataset and used in the analyses.

Type of vegetation structure	Category as percent cover	Category as coverage class
Total vegetation (all height classes combined)	Tot Veg %	Tot Veg C
Total tree (>3 m)	Tree %	Tree C
Total shrub (>0.5 m, <3 m)	Shrub %	Shrub C
Total ground (< 0.5 m)	Ground %	Ground C
Total non-native	Non-native %	Non-native C
Type of rock/sediment	**Category as percent cover**	**Category as coverage class**
Fines (<3mm)	Fine %	Fines C
Gravel (>3mm, <76mm)	Gravel %	Gravel C
Cobble (>76mm, <25cm)	Cobble %	Cobble C
Stone (>25cm, <61cm)	Stone %	Stone C
Boulder (>61cm)	Boulder %	Boulder C
Bedrock	Bedrock %	Bedrock C
Basal area of plants	Basal %	Basal C
Woody debris	Litter %	Litter C

Appendix D. Cross-reference of sample codes to water course, topographic position, and alliance. Dataset codes are * for the complete analyses, ● for the canyon analyses, and + for the wash/arroyo analyses. Canyon and Wash codes are numbers in classification analyses of canyon and arroyo/wash datasets, respectively. Bray-Curtis code is for the ordination diagrams.

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*+		1	W18	Willow	Arroyo	*Ephedra californica*
*+		2	W19	Willow	Arroyo	*Ephedra californica*
*+		3	W17	Willow	Arroyo	*Ephedra californica*
*+		4	W16	Willow	Arroyo	*Chilopsis linearis*
*+		5	W15	Willow	Arroyo	*Ephedra californica*
*+		6	W14	Willow	Arroyo	*Chilopsis linearis*
*+		7	W13	Willow	Arroyo	*Chilopsis linearis*
			W01	Willow	Upper canyon	*Populus fremontii*
*	2		W02	Willow	Upper canyon	*Baccharis sergiloides*
*●	3		W03	Willow	Upper canyon	*Acacia greggii*
*●	4		W04	Willow	Upper canyon	*Baccharis sergiloides*
*●	5		W05	Willow	Upper canyon	*Baccharis sergiloides*
*●	6		W06	Willow	Upper canyon	*Salix exigua*
*●	7		W07	Willow	Lower canyon	*Baccharis sergiloides*
*●	8		W08	Willow	Lower canyon	*Baccharis sergiloides*
*●	9		W09	Willow	Lower canyon	*Salix exigua*
*●	10		W10	Willow	Lower canyon	*Baccharis sergiloides*
*●			W11	Willow	Lower canyon	*Baccharis sergiloides*
*●	1		W12	Willow	Lower canyon	*Acacia greggii*
*+		8	W20	Willow	Arroyo	*Chilopsis linearis*
*+		9	W21	Willow	Arroyo	*Chilopsis linearis*
*+		10	W22	Willow	Arroyo	*Ephedra californica*
*+		11	W23	Willow	Arroyo	*Chilopsis linearis*
*+		12	W24	Willow	Arroyo	*Chilopsis linearis*
*+		13	W25	Willow	Arroyo	*Chilopsis linearis*
*+		14	W26	Willow	Arroyo	*Chilopsis linearis*
*+		15	W27	Willow	Arroyo	*Ephedra californica*
*+		16	W28	Willow	Arroyo	*Ephedra californica*
*+		17	W29	Willow	Arroyo	*Ephedra californica*
*+		18	W30	Willow	Upper wash	*Hymenoclea salsola*
*+		19	W31	Willow	Upper wash	*Hymenoclea salsola*
*+		20	W34	Willow	Upper wash	*Ephedra californica*
*+		21	W35	Willow	Upper wash	*Ephedra californica*

Appendix D. Continued

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*+		22	W36	Willow	Upper wash	*Ephedra californica*
*+		23	W37	Willow	Upper wash	*Ephedra californica*
*+		24	W38	Willow	Upper wash	*Hymenoclea salsola*
*+		25	W39	Willow	Upper wash	*Hymenoclea salsola*
*+		26	W32	Willow	Upper wash	*Hymenoclea salsola*
*+		27	W33	Willow	Upper wash	*Hymenoclea salsola*
*●	11		G07	Gilroy	Lower canyon	*Acacia greggii*
*●	12		G08	Gilroy	Lower canyon	*Acacia greggii*
*+		28	G09	Gilroy	Arroyo	*Chilopsis linearis*
*+		29	G10	Gilroy	Arroyo	*Acacia greggii*
*+		30	G11	Gilroy	Arroyo	*Acacia greggii*
*●	13		G01	Gilroy	Upper canyon	*Quercus chrysolepis*
*●	14		G02	Gilroy	Upper canyon	*Quercus chrysolepis*
*●	15		G03	Gilroy	Upper canyon	*Prunus fasciculata*
*●	16		G04	Gilroy	Upper canyon	*Prunus fasciculata*
*●	17		G05	Gilroy	Lower canyon	*Prunus fasciculata*
*●	18		G06	Gilroy	Lower canyon	*Acacia greggii*
*+		31	G12	Gilroy	Arroyo	*Acacia greggii*
*+		32	G13	Gilroy	Arroyo	*Acacia greggii*
*+		33	G14	Gilroy	Arroyo	*Acacia greggii*
*+		34	G15	Gilroy	Arroyo	*Acacia greggii*
*+		35	G16	Gilroy	Arroyo	*Acacia greggii*
*+		36	G17	Gilroy	Arroyo	*Acacia greggii*
*+		37	G18	Gilroy	Arroyo	*Acacia greggii*
*+		38	G19	Gilroy	Arroyo	*Acacia greggii*
*+		39	G20	Gilroy	Upper wash	*Chrysothamnus paniculatus*
*+		40	G21	Gilroy	Upper wash	*Chrysothamnus paniculatus*
*+		41	G22	Gilroy	Upper wash	*Chrysothamnus paniculatus*
*+		42	G23	Gilroy	Upper wash	*Acacia greggii*
*+		43	G24	Gilroy	Upper wash	*Chrysothamnus paniculatus*
*+		44	G25	Gilroy	Upper wash	*Chrysothamnus paniculatus*
*+		45	G26	Gilroy	Upper wash	*Chilopsis linearis*
*+		46	G27	Gilroy	Upper wash	*Chilopsis linearis*
*+		47	G28	Gilroy	Upper wash	*Chilopsis linearis*
*+		48	G29	Gilroy	Upper wash	*Chilopsis linearis*
*+		49	G30	Gilroy	Upper wash	*Chilopsis linearis*
*+		50	G31	Gilroy	Upper wash	*Chilopsis linearis*
*+		51	G32	Gilroy	Upper wash	*Chilopsis linearis*

Appendix D. Continued

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*●	19		P07	Pachalka	Lower canyon	*Prunus fasciculata*
*+		52	P08	Pachalka	Arroyo	*Acacia greggii*
*+		53	P09	Pachalka	Arroyo	*Acacia greggii*
*+		54	P10	Pachalka	Arroyo	*Acacia greggii*
*+		55	P11	Pachalka	Arroyo	*Chilopsis linearis*
*●	20		P06	Pachalka	Lower canyon	*Prunus fasciculata*
*●	21		P05	Pachalka	Lower canyon	*Prunus fasciculata*
*●	22		P04	Pachalka	Lower canyon	*Prunus fasciculata*
*●	23		P03	Pachalka	Middle canyon	*Prunus fasciculata*
*●	24		P02	Pachalka	Upper canyon	*Prunus fasciculata*
*●	25		P01	Pachalka	Upper canyon	*Pinus monophylla*
*+		56	P12	Pachalka	Arroyo	*Acacia greggii*
*+		57	P13	Pachalka	Arroyo	*Acacia greggii*
*+		58	P14	Pachalka	Arroyo	*Encelia virginensis*
*+		59	P15	Pachalka	Arroyo	*Encelia virginensis*
*+		60	P16	Pachalka	Arroyo	*Salvia dorrii*
*+		61	P17	Pachalka	Arroyo	*Encelia virginensis*
*+		62	P18	Pachalka	Upper wash	*Salvia dorrii*
*+		63	P19	Pachalka	Upper wash	*Encelia virginensis*
*+		64	P20	Pachalka	Upper wash	*Acacia greggii*
*+		65	P21	Pachalka	Upper wash	*Encelia virginensis*
*+		66	P22	Pachalka	Upper wash	*Acacia greggii*
*+		67	P23	Pachalka	Upper wash	*Acacia greggii*
*+		68	P24	Pachalka	Upper wash	*Acacia greggii*
*+		69	P25	Pachalka	Upper wash	*Acacia greggii*
*+		70	P26	Pachalka	Lower wash	*Acacia greggii*
*+		71	P27	Pachalka	Lower wash	*Encelia virginensis*
*+		72	P28	Pachalka	Lower wash	*Hymenoclea salsola*
*+		73	P29	Pachalka	Lower wash	*Hymenoclea salsola*
*+		74	P30	Pachalka	Lower wash	*Hymenoclea salsola*
*●	26		B06	Budweiser	Lower canyon	*Acacia greggii*
*●	27		B07	Budweiser	Lower canyon	*Acacia greggii*
*			B08	Budweiser	Lower canyon	*Baccharis sergiloides*
*●	28		B09	Budweiser	Lower canyon	*Salix exigua*
*●	29		B05	Budweiser	Upper canyon	*Acacia greggii*
*●	30		B04	Budweiser	Upper canyon	*Acacia greggii*
*●	31		B03	Budweiser	Upper canyon	*Acacia greggii*
*●	32		B02	Budweiser	Upper canyon	*Acacia greggii*

Appendix D. Continued

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*●	33		B01	Budweiser	Upper canyon	*Pinus monophylla*
*●	34		B10	Budweiser	Lower canyon	*Baccharis sergiloides*
*+		75	B11	Budweiser	Arroyo	*Chilopsis linearis*
*+		76	B12	Budweiser	Arroyo	*Chilopsis linearis*
*+		77	B13	Budweiser	Arroyo	*Chilopsis linearis*
*+		78	B14	Budweiser	Arroyo	*Hymenoclea salsola*
*+		79	B15	Budweiser	Arroyo	*Hymenoclea salsola*
*+		80	B16	Budweiser	Arroyo	*Hymenoclea salsola*
*+		81	B17	Budweiser	Arroyo	*Ephedra californica*
*+		82	B18	Budweiser	Arroyo	*Hymenoclea salsola*
*+		83	B19	Budweiser	Arroyo	*Hymenoclea salsola*
*+		84	B20	Budweiser	Arroyo	*Hymenoclea salsola*
*+		85	B21	Budweiser	Arroyo	*Hymenoclea salsola*
*+		86	B22	Budweiser	Arroyo	*Ephedra californica*
*+		87	B23	Budweiser	Arroyo	*Ephedra californica*
*+		88	B24	Budweiser	Upper wash	*Ephedra californica*
*+		89	B25	Budweiser	Upper wash	*Ephedra californica*
*+		90	B26	Budweiser	Upper wash	*Ephedra californica*
*+		91	B27	Budweiser	Upper wash	*Ephedra californica*
*+		92	B28	Budweiser	Upper wash	*Ephedra californica*
*+		93	B30	Budweiser	Upper wash	*Ephedra californica*
*+		94	B29	Budweiser	Upper wash	*Ephedra californica*
*+		95	B31	Budweiser	Upper wash	*Ephedra californica*
*+		96	B32	Budweiser	Upper wash	*Ephedra californica*
*		97	B33	Budweiser	Upper wash	*Ephedra californica*
*+		98	B34	Budweiser	Upper wash	*Ephedra californica*
*+		99	B35	Budweiser	Upper wash	*Ephedra californica*
*●	35		C03	Clark	Upper canyon	*Pinus monophylla*
*●	36		C04	Clark	Upper canyon	*Pinus monophylla*
*●	37		C05	Clark	Upper canyon	*Pinus monophylla*
*●	38		C06	Clark	Upper canyon	*Pinus monophylla*
*●	39		C07	Clark	Lower canyon	*Pinus monophylla*
*●	40		C08	Clark	Lower canyon	*Salvia dorrii*
*●	41		C09	Clark	Lower canyon	*Salvia dorrii*
*●	42		C10	Clark	Lower canyon	*Salvia dorrii*
*●	43		C11	Clark	Lower canyon	*Salvia dorrii*
*			C12	Clark	Arroyo	*Chilopsis linearis*
*+		100	C13	Clark	Arroyo	*Chilopsis linearis*

Appendix D. Continued

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*+		101	C14	Clark	Arroyo	*Chilopsis linearis*
*+		102	C15A	Clark	Arroyo	*Acacia greggii*
*+		103	C15B	Clark	Arroyo	*Acacia greggii*
*+		104	C15C	Clark	Arroyo	*Chilopsis linearis*
*+		105	C16	Clark	Arroyo	*Acacia greggii*
*+		106	C17	Clark	Arroyo	*Acacia greggii*
*+		107	C18	Clark	Arroyo	*Acacia greggii*
*+		108	C19A	Clark	Arroyo	*Chilopsis linearis*
*+		109	C19B	Clark	Arroyo	*Acacia greggii*
*+		110	C20	Clark	Arroyo	*Chilopsis linearis*
*+		111	C20B	Clark	Upper wash	*Acacia greggii*
*+		112	C21	Clark	Upper wash	*Acacia greggii*
*+		113	C21B	Clark	Upper wash	*Acacia greggii*
*+		114	C22	Clark	Upper wash	*Acacia greggii*
*+		115	C22B	Clark	Upper wash	*Acacia greggii*
*+		116	C23	Clark	Upper wash	*Acacia greggii*
*+		117	C23B	Clark	Upper wash	*Acacia greggii*
*+		118	C24	Clark	Lower wash	*Acacia greggii*
*+		119	C24B	Clark	Lower wash	*Acacia greggii*
*+		120	C25	Clark	Lower wash	*Acacia greggii*
*+		121	C25B	Clark	Lower wash	*Acacia greggii*
*+		122	C26	Clark	Lower wash	*Acacia greggii*
			WB01	Winston	Upper canyon	*Pinus monophylla*
*●	44		WB02	Winston	Upper canyon	*Pinus monophylla*
*●	45		WB03	Winston	Upper canyon	*Baccharis sergiloides*
*●	46		WB04	Winston	Upper canyon	*Baccharis sergiloides*
*●	47		WB05	Winston	Upper canyon	*Baccharis sergiloides*
*●	48		WB06	Winston	Lower canyon	*Baccharis sergiloides*
*●	49		WB07	Winston	Lower canyon	*Baccharis sergiloides*
*●	50		WB08	Winston	Lower canyon	*Prunus fasciculata*
*●	51		WB09	Winston	Lower canyon	*Prunus fasciculata*
*●	52		WB10	Winston	Lower canyon	*Prunus fasciculata*
*+		123	WB11	Winston	Arroyo	*Prunus fasciculata*
*+		124	WB12	Winston	Arroyo	*Prunus fasciculata*
*+		125	WB13A	Winston	Arroyo	*Prunus fasciculata*
*+		126	WB13B	Winston	Arroyo	*Chilopsis linearis*
*+		127	WB14	Winston	Arroyo	*Prunus fasciculata*
*+		128	WB15	Winston	Arroyo	*Prunus fasciculata*

Appendix D. Continued

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*+		129	WB15B	Winston	Arroyo	*Chilopsis linearis*
*+		130	WB16	Winston	Arroyo	*Chilopsis linearis*
*+		131	WB16B	Winston	Upper wash	*Hymenoclea salsola*
*+		132	WB17	Winston	Upper wash	*Hymenoclea salsola*
*+		133	WB17B	Winston	Upper wash	*Hymenoclea salsola*
*+		134	WB18	Winston	Upper wash	*Hymenoclea salsola*
*+		135	WB18B	Winston	Upper wash	*Hymenoclea salsola*
*+		136	WB19	Winston	Upper wash	*Hymenoclea salsola*
*+		137	WB19B	Winston	Upper wash	*Hymenoclea salsola*
*+		138	WB20	Winston	Upper wash	*Hymenoclea salsola*
*+		139	WB20B	Winston	Lower wash	*Hymenoclea salsola*
*+		140	WB21	Winston	Lower wash	*Hymenoclea salsola*
*+		141	WB21B	Winston	Lower wash	*Hymenoclea salsola*
*+		142	WB22	Winston	Lower wash	*Hymenoclea salsola*
*+		143	WB22B	Winston	Lower wash	*Hymenoclea salsola*
*+		144	WB23	Winston	Lower wash	*Hymenoclea salsola*
●	53		N01	New York	Upper canyon	*Quercus tubinella*
●	54		N02	New York	Upper canyon	*Quercus tubinella*
*●	55		N03	New York	Upper canyon	*Quercus tubinella*
*●	56		N04	New York	Upper canyon	*Quercus tubinella*
*●	57		N05	New York	Upper canyon	*Quercus tubinella*
*●	58		N06	New York	Upper canyon	*Quercus tubinella*
*●	59		N07	New York	Lower canyon	*Quercus tubinella*
*●	60		N08	New York	Lower canyon	*Quercus tubinella*
*●	61		N09	New York	Lower canyon	*Quercus tubinella*
*●	62		N10	New York	Lower canyon	*Quercus tubinella*
*●	63		N11	New York	Lower canyon	*Quercus tubinella*
*●	64		N12	New York	Lower canyon	*Quercus tubinella*
*●	65		N13	New York	Lower canyon	*Quercus tubinella*
*			N14	New York	Arroyo	*Chilopsis linearis*
*			N15	New York	Arroyo	*Chilopsis linearis*
*+		145	N16	New York	Arroyo	*Chilopsis linearis*
*+		146	N17	New York	Arroyo	*Chilopsis linearis*
*+		147	N17B	New York	Arroyo	*Chilopsis linearis*
*+		148	N18	New York	Arroyo	*Chilopsis linearis*
*+		149	N18B	New York	Arroyo	*Acacia greggii*
*+		150	N19	New York	Arroyo	*Chilopsis linearis*
*+		151	N19B	New York	Upper wash	*Acacia greggii*

Appendix D. Continued

Dataset code	Canyon code	Arroyo/ wash code	Bray-Curtis code	Water course	Topographic position	Alliance
*+		152	N20	New York	Upper wash	*Acacia greggii*
*+		153	N20B	New York	Upper wash	*Acacia greggii*
*+		154	N21	New York	Upper wash	*Acacia greggii*
*+		155	N21B	New York	Upper wash	*Acacia greggii*
*+		156	N22	New York	Upper wash	*Acacia greggii*
*+		157	N22B	New York	Upper wash	*Acacia greggii*
*+		158	N23	New York	Upper wash	*Acacia greggii*
*+		159	N23B	New York	Lower wash	*Acacia greggii*
*●	66		M01	Mitchell	Upper canyon	*Quercus chrysolepis*
*●	67		M02	Mitchell	Upper canyon	*Pinus monophylla*
*●	68		M03	Mitchell	Upper canyon	*Pinus monophylla*
*●	69		M04	Mitchell	Upper canyon	*Pinus monophylla*
*●	70		M05	Mitchell	Lower canyon	*Prunus fasciculata*
*●	71		M06	Mitchell	Lower canyon	*Chilopsis linearis*
*●	72		M07	Mitchell	Lower canyon	*Chilopsis linearis*
*●	73		M08	Mitchell	Lower canyon	*Chilopsis linearis*
*●	74		M09	Mitchell	Lower canyon	*Chilopsis linearis*
*+		160	M10	Mitchell	Arroyo	*Chilopsis linearis*
*+		161	M11	Mitchell	Arroyo	*Chilopsis linearis*
*+		162	M12	Mitchell	Arroyo	*Chilopsis linearis*
*+		163	M13	Mitchell	Arroyo	*Chilopsis linearis*
*+		164	M14	Mitchell	Arroyo	*Chilopsis linearis*
*+		165	M14B	Mitchell	Arroyo	*Chilopsis linearis*
*+		166	M15	Mitchell	Arroyo	*Chilopsis linearis*
*+		167	M15B	Mitchell	Arroyo	*Acacia greggii*
*+		168	M16	Mitchell	Arroyo	*Acacia greggii*
*+		169	M16B	Mitchell	Arroyo	*Acacia greggii*
*+		170	M17	Mitchell	Arroyo	*Acacia greggii*
*+		171	M17B	Mitchell	Arroyo	*Acacia greggii*
*+		172	M18	Mitchell	Arroyo	*Acacia greggii*
*+		173	M18B	Mitchell	Arroyo	*Chilopsis linearis*
*+		174	M19	Mitchell	Arroyo	*Chilopsis linearis*
*+		175	M19B	Mitchell	Upper wash	*Chilopsis linearis*
*+		176	M20	Mitchell	Upper wash	*Chilopsis linearis*
*+		177	M20B	Mitchell	Upper wash	*Chilopsis linearis*
*+		178	M21	Mitchell	Upper wash	*Chilopsis linearis*
*+		179	M21B	Mitchell	Upper wash	*Chilopsis linearis*
*+		180	M22	Mitchell	Upper wash	*Chilopsis linearis*
*+		181	M22B	Mitchell	Upper wash	*Chilopsis linearis*

Appendix E. Indicator species and values for groups of topographic position in the complete dataset. Number of samples is denoted by n, and significance is denoted by p. Codes for indicator values are canyon=1, arroyo=2, and wash=3. See Appendix B for species codes.

No groups excluded					One group excluded							
Canyon, arroyo, wash n=258					Canyon, arroyo n=168			Canyon, wash n=164			Arroyo, wash n=184		
A. Species that discriminate on canyon group as compared to the arroyo and wash groups												
Species	1	2	3	p	1	2	p	1	3	p	2	3	p
elele	54	1	0	0	54	1	0	59	0	0	6	0	0.028
lichen	51	0	0	0	54	0	0	54	0	0	2	2	0.999
pimo	50	0	0	0	50	0	0	51	0	0	2	0	0.52
base	46	1	0	0	48	1	0	51	0	0	7	1	0.135
moss	43	1	2	0	51	1	0	49	2	0	4	6	0.613
brca3	42	1	0	0	43	1	0	48	0	0	5	0	0.17
spam2	35	18	10	0	47	23	0.001	52	15	0	32	19	0.114
samo3	33	1	0	0	35	1	0	37	0	0	4	1	0.44
cali4	31	0	0	0	31	0	0	31	0	0			
euin2	31	1	0	0	31	1	0	35	0	0	5	0	0.049
pume	30	0	0	0	30	0	0	34	0	0	4	0	0.13
gumi	28	10	4	0	34	12	0.006	40	5	0	21	8	0.072
pofel	28	0	0	0	28	0	0	28	0	0			
erwr	27	0	0	0	27	0	0	28	0	0	1	0	0.999
juos	24	0	0	0	24	0	0	24	0	0	1	0	0.999
ectr	23	0	0	0	23	0	0	24	0	0	1	0	0.999
rhcri	23	0	0	0	23	0	0	23	0	0			
gaan2	22	0	0	0	22	0	0	23	0	0	1	0	0.999
ercus	20	0	0	0	20	0	0	20	0	0			
erhes	19	0	0	0	19	0	0	19	0	0			
gapa4	19	0	0	0	19	0	0	19	0	0			
acpa	18	0	0	0	18	0	0	18	0	0			
gafl	18	0	0	0	18	0	0	18	0	0			
gamu	18	0	0	0	18	0	0	18	0	0			
juma	18	0	0	0	18	0	0	18	0	0			
tara	17	0	0	0	17	0	0	18	0	0	1	0	0.999
keanm	16	0	0	0	16	0	0	16	0	0			
muri2	16	0	0	0	16	0	0	16	0	0	1	0	0.999
sool	16	0	0	0	16	0	0	16	0	0			
brdi	16	0	0	0	16	0	0	16	0	0			
brlom	14	0	0	0	14	0	0.002	16	0	0	2	0	0.742
trra5	14	1	0	0	14	1	0.007	18	0	0	4	0	0.118
qutu	13	0	0	0	13	0	0	15	0	0	2	0	0.485
henac	13	0	0	0	13	0	0.003	15	0	0	2	0	0.482

Appendix E. Continued

B. Species that discriminate on canyon group, and decrease in arroyo and then wash groups

	No groups excluded				One group excluded								
	Canyon, arroyo, wash				Canyon, arroyo			Canyon, wash			Arroyo, wash		
Species	1	2	3	p	1	2	p	1	3	p	2	3	p
arlu	70	1	0	0	70	1	0	77	0	0	9	0	0.006
rhtr	70	1	0	0	70	1	0	77	0	0	14	0	0.001
erli6	61	2	0	0	62	3	0	73	0	0	14	0	0
prfa	57	10	1	0	61	11	0	77	1	0	32	3	0
yuba	52	4	0	0	54	4	0	64	0	0	16	1	0.001
epvi	48	4	0	0	49	4	0	60	0	0	16	0	0
brma3	45	31	14	0	57	40	0	68	21	0	57	25	0
lori3	45	2	0	0	45	2	0	54	0	0	12	0	0.002
acsp1	43	5	1	0	47	6	0	57	1	0	17	2	0.005
brte	37	1	0	0	37	1	0	43	0	0	10	0	0.001
opph	33	6	0	0	33	6	0.001	45	0	0	19	0	0
fapa	20	3	0	0	20	3	0.004	26	0	0	11	0	0.006
gusa2	25	8	1	0	29	10	0.005	38	2	0	19	3	0.007
oper	26	2	0	0	26	2	0	34	0	0	10	0	0.003

C. Species that discriminate on canyon and arroyo groups, as compared to wash group

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
oece2	25	14	2	0	29	16	0.086	39	4	0	27	4	0
pepap	25	19	6	0.005	31	24	0.378	39	9	0	33	10	0.002
cine	20	4	0	0	20	4	0.015	30	0	0	14	0	0
vipar	14	15	3	0.113	17	18	0.841	26	5	0.002	25	5	0.004

D. Species that discriminate on canyon group as compared to wash group

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
Arpu9	18	9	3	0.002	22	11	0.139	27	4	0	17	5	0.042
Ecen	16	12	3	0.055	19	15	0.512	25	5	0.006	21	6	0.023
Fecy	9	2	0	0.002	10	2	0.138	14	0	0	6	0	0.063
mimup	9	5	0	0.025	10	5	0.401	15	1	0.004	10	1	0.026
putr2	7	3	0	0.028	8	3	0.265	11	0	0.003	6	0	0.069

E. Species that do not discriminate on landform

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
bejua	1	9	7	0.263	2	15	0.029	2	12	0.082	10	8	0.75
caan7	2	5	0	0.119	2	5	0.549	4	0	0.176	8	0	0.03
epne	4	14	16	0.163	7	24	0.025	7	27	0.011	18	20	0.717
erfa2	15	10	17	0.455	25	15	0.199	21	23	0.816	15	26	0.124
erpl3	0	3	3	0.621	1	5	0.313	1	6	0.158	4	4	0.999
esvid	2	7	1	0.111	3	10	0.211	4	3	0.776	10	2	0.104
gaco5	4	3	4	0.961	6	4	0.783	5	6	0.999	4	6	0.805
krer	2	6	9	0.189	4	10	0.258	3	14	0.081	7	11	0.552

Appendix E. Continued

No groups excluded					One group excluded								
Canyon, arroyo, wash n=258					Canyon, arroyo n=168			Canyon, wash n=164			Arroyo, wash n=184		

E. Continued

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
mibi8	7	13	15	0.394	12	21	0.255	11	23	0.137	17	20	0.759
mipu6	11	5	3	0.047	15	6	0.193	16	4	0.04	9	5	0.549
niob	3	4	2	0.665	4	6	0.795	4	3	0.767	7	3	0.422
opapcc	15	19	10	0.216	20	26	0.488	23	16	0.338	29	16	0.083
opba2	4	4	9	0.326	8	7	0.999	6	12	0.418	5	13	0.223
phca8	7	15	3	0.036	9	19	0.211	13	6	0.197	22	5	0.008
phcr1	1	7	5	0.293	1	11	0.079	2	9	0.133	8	6	0.831
same1	7	14	18	0.158	11	23	0.148	10	27	0.028	18	24	0.444
stpa4	13	18	27	0.031	22	29	0.372	20	39	0.016	25	37	0.109
thmo	13	9	8	0.318	19	12	0.409	19	11	0.282	14	12	0.872
trmu	7	10	3	0.219	9	13	0.596	12	5	0.296	16	5	0.059
yusc2	9	12	8	0.713	13	17	0.719	15	13	0.836	17	12	0.54
aslef	3	4	0	0.248	3	4	0.999	7	0	0.016	7	0	0.014

F. Species that discriminate on wash group as compared to canyon group

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
crust	4	10	19	0.017	8	19	0.152	7	28	0.005	13	24	0.139
opra	0	2	12	0	0	7	0.029	0	17	0	2	12	0.062
psarm	0	2	12	0	0	7	0.02	0	17	0	2	12	0.038
chal11	0	3	11	0.003	1	7	0.125	0	17	0.001	3	13	0.093
mupo2	1	4	10	0.03	2	9	0.189	1	16	0.01	5	12	0.235
alin	0	2	9	0.01	0	5	0.076	0	12	0	2	9	0.115
psco2g	0	5	9	0.027	0	10	0.021	0	15	0	5	10	0.424
lefrf	0	3	7	0.043	0	9	0.013	0	12	0.001	3	7	0.46
ppec	0	3	6	0.086	0	7	0.019	0	10	0.003	3	6	0.584

G. Species that discriminate on wash group only, as compared to canyon and arroyo groups

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
lyan	2	6	24	0	4	14	0.085	2	34	0	8	29	0.004

H. Species that discriminate on wash group, and decrease in arroyo and then canyon groups

Species	1	2	3	p	1	2	p	1	3	p	2	3	p
adco	0	2	21	0	0	12	0.001	0	26	0	2	21	0
scba	3	15	34	0	6	30	0.004	5	52	0	18	40	0.004
amdu2	0	13	36	0	0	34	0	0	56	0	14	37	0.001
chpa	0	4	37	0	0	17	0	0	49	0	4	37	0
latr	0	18	51	0	0	45	0	0	80	0	18	52	0
hysa	0	25	58	0	1	60	0	1	94	0	26	61	0

Appendix E. Continued

	No groups excluded				One group excluded								
	Canyon, arroyo, wash n=258				Canyon, arroyo n=168			Canyon, wash n=164			Arroyo, wash n=184		
I. Species that discriminate on arroyo and wash groups as compared to the canyon group													
Species	1	2	3	p	1	2	p	1	3	p	2	3	p
erci6	11	35	30	0.002	18	54	0	19	50	0	45	39	0.332
enva	2	12	28	0	3	25	0.002	2	43	0	13	32	0.016
erin4	0	15	26	0	1	33	0	1	44	0	17	28	0.138
amer	0	19	25	0	1	37	0	1	47	0	21	27	0.441
erpu8	0	20	19	0.006	1	37	0	1	36	0	21	20	0.999
isar	0	18	8	0.001	0	29	0.001	0	20	0	19	8	0.118
epca2	0	16	10	0.005	0	30	0.001	0	22	0	16	11	0.432
sear8	0	6	18	0	0	16	0	0	29	0	6	18	0.042
brin	0	8	17	0.002	0	21	0	0	28	0	8	17	0.173
krgr	0	8	13	0.009	0	17	0.001	0	22	0	8	14	0.479
yubr	0	6	11	0.024	0	14	0.003	0	18	0	6	12	0.354

J. Other, species that discriminate variously

	1	2	3	p	1	2	p	1	3	p	2	3	p
acgr	15	39	16	0	21	55	0	27	29	0.823	54	22	0
chlia	3	31	7	0	4	42	0	7	17	0.204	38	8	0
dawr2	6	0	4	0.108	11	0	0.006	7	5	0.802	0	9	0.005
phhe4	20	2	7	0.001	28	3	0.001	24	8	0.026	5	14	0.122
enfa	0	8	2	0.006	0	12	0.007	0	4	0.211	9	2	0.122
phar5	0	8	1	0.01	0	11	0.003	0	4	0.13	8	1	0.155
sado4	4	24	13	0.003	7	36	0	9	25	0.037	31	17	0.081
seflm	1	19	5	0	1	26	0	2	12	0.079	21	6	0.019
cora	4	7	0	0.092	4	8	0.546	8	0	0.039	12	0	0.004

Appendix F. Twinspan table for the canyon dataset. See Appendix B for species codes. Appendix D for plot codes. Twinspan table results are cover values from Table 5.

Species codes	Plot cover values	
	233 1 233223777711111112225554444444423334223311666666665665555554	
	84114567890239026730123412567890120125678912337890455634678923458013456794	
base	3431533333342111223---------------21233433------------------1232322----122	0
opba2	1-1--------11-111--------------1------------1------------------------1--1-	0
fecy	-11-1---11--1-----1---------11----------------------------------1---------	10
juma	111-11111111----------------------1---------------------------------------	10
jume4	-12-131122--	10
keanm	------1-1--1-111112-------1--1-------------------------1------------------	10
lyan	-1-1---111-112--	10
muri2	1-4-13211111--	10
saex	2----41131----------------------------1-----------------------------------	10
scba	11-1-11111111---12------------------1--------------------------------1----	10
sool	11--11-11111---1--	10
tara	111-1111-11-----------------------1-------------------------------------1-	10
tydo	-12-11111-1---	10
yusc2	-111111111111111111-----11--	10
erfa2	1-1111111-112211111-----11--------11111111------------------1--1---------1	11
hysa	---1------------23----------------111-------------------------------------	11
mefr	1---1---1--1-11-----------111---	11
phca8	21-1---1---11-1-11--1-1111--11--	11
pomo	211-----1----------------------------11111--------------------------------	11
ardr	----------------------------------11111111-------------------------------1	100
acgr	221111111112222222-111122221222222111--1-2---------------------1----------	101
chlia	-2-2--2---------1---434222---1------2------------------------1-1----------	101
enva	-1----------2---11------11---11---1---------------------------------------	101
erci6	211-1111111111-111---1-1111222-11-111111-1---1----------------------------	101
mibi8	---1-1--1-1-1111--------11111111--1--1--1---------------------------------	101
gumi	111111111111111111111---------11112111111111----111--------1--------------	110
lori3	1111111111112211111-----111111----1-11-111------------------1111-11----11-	110
oece2	1111111111111111---11--11--1--1111111-----1--1-11-------1111--1-----------	110
spam2	111111111111111111111111111111111111111111---11111111-------1--1111--11-1-	110
ecen	111----1--11----1----1--111111111-11--11----11-----1----1----------------1	111
euin2	-----1-1---11-11--11111-111111----1111---1-------------1--11--------------	111
opapcc	1111--11---1211111-11---11--1211---21-1111-11---------------1-1-----------	111
samo3	----1-1----11111-1111-1-111121-1---111-------1--1111---1------------------	111
stpa4	11-111-----12111111-111-1111-11111111--------1----11------1-----------1---	111
vipar	11-2-111111-1---1--22312322113-------------------------1--11-11-----------	111
putr2	------------------1----------------1111121-------------------------1-1----	111
same1	1---1---------1--1--1-1------112311----2-1-1-1----21-----------1----------	100
br1om	-------------------21122-------111-----------2----2-------22--------------	1010
crust	----1------11------111-------11-1----------11----1111---------------------	1010
gaan2	--------------------11--111111-----11--11--------------11122--------------	1010
mimup	------------------------1--1-1--1----1-11111-------1---11-----------------	1010
pepap	-------------------1111112111-111111111111111111111111111111-11----------1	1010
prfa	--212121---3223323233332323322333333322222312222222311-1-123-1111----1--11	01010
epne	11-----------1--11-1--11------1---1---------------------1111--------------	1011
epvi	-111111111111211000-----1111221112----11--11-11221111111-1---------------1	1011
arlu	--112112111211-----1111-111111111111111111---2--1-11--11111111111111111111	110
arpu9	11111-11-111-1-----1-1-1-1---11-1-----------1-----11---1111--1-1----------	110
brma3	22123322222332122221111122121212221111111211211111211211111111111111111111	0110
cine	11-1----1--1-1-11-------------111--1-1----11-------1--------1---1-1----11-	110
erli6	11-111111111111111111-11-11111-----11122111211---11-----111111-1111--1-11-	110
acspl	11111111111111111121----111-1111111-1-------11---111---1111-1111-11-------	111
ercus	--1-11-11-1--111--------------------------------------1----------1--1-1111	111
mipu6	------------------------------1111-11-11111-111111--------1---------------	1000
sado4	------------------------12----32111-1--111333---23------------------------	1000
thmo	--------------1--11111--1----111111-------1111111111---1--1---------------	1000
opph	-------------------111111121111111--------22111112121-11111-1-1--11-------	1001
pume	------------------11111-11222-1-12---------1-122221111-2---1--------------	1001
rhtou	-----------------------------------2--12-2--------------22231-------------	1001
trmu	-1-----------------11--------11111--------1----111------11-1----1---------	1001
brca3	11--1111111-1-1--11------------1--11-11111--------111-11211------1-11-1112	1010
moss	-1111111111--------1------111-1-----11111--1----1-11111111-11-11111111-111	1010
brte	-------------------11111---------1-1-33311-1-1211111211---11-1--1-1-1--112	10110
phhe4	1-----------1-------------1-1-1111-1-1-1-1---1-1-111--111-11--111----1-11-	10110
rhtr	--1-2121-112112----2-----121--211221-2222222221112331121221122122221122222	10110
trra5	-------------------1-1--------1111----------------11---1--1-111-----------	10110
yuba	-------------------2121121111111110--1111112211111121111111111-1111-111111	10110
erwr	----1-1----1------1---------------1--11111-------------1----11111-111111--	10111
elele	--1------111--11--1------111-11-11---111---11111-111111111111-111111111111	11000
gusa2	-------------------11111111111---1---------1-111-111-1-1-1-11111111111111-	11000
lichen	1---1-1----1-111-111-------1------11-111111----111-11211111-111111111111112	11000
oper	-----------------------------------1111111----1111--1111-1---11-1-11111111	11000
erhes	---------------------1----1---1-1------------11---1-1111--11------------1-	11001
henac	-------------------1------1-----11----------------11---11111--------------	11001
pimo	--1--------1---2--22-----------------22121122-333223332223-211-12123332211	11001
agvi	111--11-1--11-	11010
asnu3	--1----------------------------------1--------------------------11-1111---	11010
brdi	21----------------------1-------------1---------------------1111111-----1-	11010
bocu	---1--------111111-1--111-	11011
gamu	--------------------------------------1--1--------11------1-1---1-11111111	11011
pemu	----1---1-1-111-11111-	11011
qutu	--4323233333332-	11011
acpa	1-------------1----------11------------1-----11--11111-11111-------1--1111	11100
ectr	--1------------1--1-------1------1----------1111-111111---1--------11-11--	11100
rhcri	---------------1--1-------11-------1-11---------------222222-------211--12	11100
arpe2	--------------------1---------------------------------11111-----11-11-111-	11101
asasa	--11--11---1------------1111--	11101
cali4	-----1-------------------------1------1---1--111111111-11111----1-1-11-11-	11101
fapa	---23211132-----1---2211111223111-	11101
gapa4	--1---1111111-----1-1--1111-	11101
juos	---------------------------------------11------122122121-2-1----1-1-22-21-	11101
peea	--------------------------1-------------------1-----1---11111----1-111---1	11101
pofe1	--------------------------1------------------1-11-11211111--1---1111111111	11101
artr2g	---1211---1111------------------	11110
cein7	--1111111-1---------------	11110
cora	--1--------------------------------1------122---11------------------------	11110
lesam	--211111-------1-----1	11110
quch2	--------------------------------------1---------------5253---------31-----	11110
fran	--21----1---1122-----1---1--2-	11110
gaf1	-------------------------------------1--------3311--31--2322----1--------4	11110
sylo	--2--1--32---1----------------	11110
	00000000000000000000000000000000000000000000011111111111111111111111111111	
	00000000000000000011111111111111111111111110000000000011111111111111111111	
	00000000001111111100000000000000000000111111100000000111000000111111111111	
	00111111111000000010000000000001111100111110001111111 000000000011	
	0111111110000011 00000111111 11 00001111111	

Appendix G. Twinspan table for the arroyo/wash dataset. See Appendix B for species codes, and Appendix D for plot codes. Twinspan table results are cover values from Table 5.

Species codes	Plot cover values	
	1111111111111 1111111111 1111111111111111111 111111111111111111111 1111 111111111111	
	4455555545555555666666666677777011111122255555000000001111022224422233333366666666667777777777788334434444445533333442333333444442 11111222 111117777787888888888999999999922222	
	7803578991246789012345678901234945678901223456023456780123134565678901234562013456789014235678901782390145790112454689036789234018123565672856778901349567928034561789012345678901234	
ESVID	-------------11-11-11-1-11-----1---------11111111-1-----1--	00000
gaco5	------------1--1111111111-1----------1--11------------------------1---------11-1---	00000
gumi	1-----------1111-1-1-11-1111111--1-111-1111111111111111-11111-11---------------------1----------------------1------------------1-----------1--------------------------------	00000
mesp2	---------------11----------1-2--------------1111-----------------1---1----------	00000
MIPU6	------------1--111111111------1111------11-1-----1-11----1---1-1--1---	00000
MUPO2	--------1-1111111-1-11--1-----11111111---1111----1----111--------------1------------------------------------1--	00000
ORC04	----------------------11-11111---1---	00000
yuba	------------11111-111---------1---------1111-111-1-----1---------11--------1---	00000
yubr	------------1-1111-11-1-1--2221111-1-111----11111 1111-1111---	00000
ACSP1	------------1111----1----------1----1---11111-111111--111-1---1--111---1------------------------------------1--	00001
CAAN7	----------------11---------------------1---1-1-11---------1---------1--	00001
cine	-------------1111----------------------11111----11-----------1----1--	00001
cora	-------------1-------------------1------1111121-1---1-1----1---	00001
fapa	--12211111---1---	00001
krer	---1111--11-1-111---1-1---1111-------1--11-1111111--1--1-----------1-11-------------------------------------1-----------1--	00001
MIMUP	-11-----------------------------------1-111111111-11----1---	00001
OPER	------------1---------------------------11----11-1--------1-1--	00001
rhtr	--1-------------------------------------11111-111--------1-----1----------1---	00001
sado4	122221112112132232321111-11111113322111111332322232332213231111121111212211------1-----------------11-111-1-----1-------1--	00001
ARPU9	------------111111-1--1-111--11---1-11---1111-------1-11--1------1111111--111--1---------1--	0001
BRTE	-------------1-----------------------------111---------1--1---------------1-------1--	0001
opph	----------------------------1---------11---11111-1111--1-------1---------1111-----11-----1---	0001
prfa	221111111111----1-----------1--1-1-------2221221212111--1-22132333211-------22-------------------------------1---1---1------------------------------1-------------------	0001
TRMU	------------11111--1111-111-------1--1-111111----1111111---------1-1--111--11-------1---	0001
lefrf	11-----------111---1-111-----------1-----1-1-------------------1-------------------------------1--------1---1111	00100
samel	1121-1111111111-112111112122211---11111111111111122121-112-11---111--1---11---1----------1----------1------------1----------111---------------------------111-11---111---1--11-----	00100
ACGR	2322212133332211-1-11-22222-1--32222323322223222212222333211222232323212222221222333221111-----221-1111-11-111--11-11-1------1-1-1111111----1--------111-11111111-111-----11------2	00101
ALIN	---------------1----1--1-1-11-------1-11----------------1-----------------------11--11-------------------1--------1---	00101
amer	11211-1111-211--11111112111----12122222322111223231232221223333112-------1-----------------------112211211-1111211-11212111------3---	00101
CHAL11	------------111-11--1-11-11111----------1-111--111111------1-------------------1---1---------------------------------------	00101
ECEN	------------1111111111111111--111-------11111111-1-----1-----1----1-----1-11-111-1111-1-------------------------11----------1--	00101
enva	------------222221122222222000-111111111111112---1-1111-1111-------111112----------1-1-1-1--------121 11111-11111-11-11---11111-21-11-------------------------------------1------------	00101
epne	1--111--11111111111-1111111111111111-11111-1112-1-111-1111------------------2111111111111-11--------11---1------1---2---------1-11--	00101
erli6	-------------------------------------1---11---1-1----1----11------1--11---------------------1--1--------------------	00101
opapcc	----1--11---11111111--11111111111-111---1111111111111-1-1--1-11111-1-1-111-1-11111111111---11-1------------------1111-1--111--1---1------------------------1----------1---------------	00101
OPBA2	------------11-11-11-11111----------------1-111-11-----1--1-------------1--------------1--11-111----------------1---------1-------1-----------------------------------11-------1--	00101
PHHE4	11------------1-----1--111-1-------------11111-------------------1---------1--------------------1-1 1111111111-----11------------------------1--------------------------------------1	00101
thmo	------------11--111-11--1------1----11--111-111111-1---11---1---11-1111111-------------------------1111-11-------11---11--1-11---1---------------------------------1----------------	00101
yusc2	11111111111-1-111111--11--11111-1-------1---11-----------1----1-1-11111111111---1---1----1--------------------------------111--------------------------1-------1-----11--1------	00101
ERPU8	-1-1--111----111---111-1-11--1111-1111111-1111-11-11111111-----1----1-11111-11-11111111111111111-11111---111-11--11---	00110
OECE2	------------11111--1111111---------1---11111----11111--------1---11-1---111111111111-1111-11-------------------------------1--1--	00110
pepap	------------111111111111-11-----1111111-111112111111111-11111---111111111111111111111111111-111---------1-11------1-1---	00110
PSCO2G	------------111-11-11-1-111-11------11---------------------------1-11111--------------------1-11-----1---------1--	00110
base	---11-----------------------21-22-211--	00111

Appendix G. Continued

```
enfa     ---------------------------------------------------------------------------------------1111111111111111-1-------------------------------------------------------------------------------------------- 00111
epvi     ---------------------------------------------111------1------1-------1111121111----11----------------1--1--------------------------------------------------------------------------------------- 00111
fecy     ------------------------------------------------------------------------1----1--1---111------1-----------------------------1---------------------------------------------------------------------- 00111
bejua    ------------------2-1--------------------------------------------------------11-11111111111112111122121--1--1--1-------------------11---------------------1--------------------------1-- 0100
gusa2    ---------1----------------------------------------------------------------1111121111111--11-1211-11111-1-11-1-11---------------------------------------------------------------------------- 0100
POGR5    ----------------------------------------------------------------------------11--1--------1----11-11----------------------1------------------------------------------------------------------- 0100
vipar    ---1--1---------1------------------------1-------------------1--2433333333321211222211111111-1---3-2 11111-11-1-----1---------------------1--11---------1---------------------------- 0100
phca8    11----1-------------------------11111111----------1--11-11-1-1--111--11---11-1-11111111-1--------111 ----------------------------------1-----------------1-1-----------1-------------- 0101
PHCR1    -------------------------------------------1------1------1-1----------------111111111-111-11-1-------------------11-1-----1---11-------------------------------------------------------- 0101
PLRI3    -----1-------11-------------------------1--------------------------------11----------1-------------1-----------1-------------1----------------------------------------------------------- 0101
ERIN4    ------------11111111111111111111111111--1111---11-1-1---------111111-1--1--1-1111111-111111111111 11--------11---11--1-1111-111--------------------------1----1----------1---------1 01100
lyco2    11---1-1--111-------------------------1--------------------------------------------------------------------------------------1------------------1----------------------------- 01100
spam2    -1--1---11---111-11111-11111111-1-1-111-111111-1---111--1-111-1-1-111-111111-1111111---11--1-1---11--111111111111-111111-----------11-1-----------------1-----1-11------------1--- 01100
stpa4    1--------111-1111111111111111-1-1-1111111111111-11---111111-111-1111111-1111-11-1-1-111--11111111111 11111111111-11111-1-111----111--11-1-1-11---1-----11-1---------11-----------1-11- 01100
erfa2    ---------1------------1--11---11-1111111------1--1111-11--111111111111111111-------------------111 11111111-1111-11111111111-1-------------22---------11-------1---------------1-1- 01101
mibi8    -1----1------1111--111111111----1---1----1111----------111--1--1----1111--1111111-----11-----1---111-111------1111111-11111111111------11------1--1------------------------------- 01101
MOSS     ------------1-----111--11-11--1---------11-----------------1------------------------------------------1-----1---1---1-----1------------------------------------------------------ 01101
chlia    22312-----------------------------1-1--------3113-21321214---333-2--------43453431212-3-43333333--1-2-3122232----33333------------2--2---2----2231322-532111------------------------ 0111
chpa     111-----12---------2-111-11-------------------------------------1--------1-1---------------1-----1-13331333333-----23-------1----------1-2-2-----1---------------------------------- 0111
NIOB     -----------------1---111--1---------------------------------------1-----------------1-11-1-------1-1-------1----------11----------1-------------------------------------------------- 0111
ADCO     ---1--1-11-1111-11111111111111-1111-111111-1-111111-11--21---111---------------------------------1---11---1-1---11--11----1--111-----1-1-1-------1----11111111111111-11111111 100
dawr2    -1-----11--11------------------------------------------------------------------------------------1-1---------1----1-------------------1------------------------------------------- 100
erp13    ---11-111--11------------------------------------------------1--------------------------------------------1-------------------111-1------------1------------------------------------ 100
lyan     -1-11-11-11--1111-11111111-111111-11111111---------1--1-----------1-----1-------------1------------1-----------------------1-----------1-------11---1-111---11-111-1111111-1---- 100
brin     --1-1-12-1-11--1-1--1111--21---------------------1-----------------------------------------1-11----------------1-21212---1122--------------111211-11111-11-1-1------------------------------ 1010
BRMA3    1-----------1-2111121111111111111-1-111-121121111-11111-1-11111111221222122211111111111111111-11-221 11121111111111111211111--------1111121111----11111-1-1111111111111111112111111---- 1010
ERCI6    --1111--1111111111121111111111-1-1-111-1112111111 11111-1-111-1---12111112211111111----11-11----111 11111111-1111-1111111111--1111111-11111111112111 211111112111111111111111111111 1010
lori3    -------------------------------------------------------11-----11---------1-1---------------------------------1-----------------1------1-----1--1------------------------------------- 1010
CRUST    -11-----1--11---------1-1---11--11--------1-1-1111 111---1------11---------1-111111111---1---11111----------------111-1--1-11-11-1----11------------------------------111111111111-112-- 1011
cupa     ---------------------------------------------------------------------------------------------------11----1---1---1---1--1-----------1---1----------------1------------------------- 1011
krgr     ------------1---1-------------------------------------------1--1-------11---1---1-1--1-1-------111--1-1-----1111-1-11-1-1111111-------------------------11---1-----------111--11-1-- 1011
latr     ---22-121231--11---1-11-1-111221121111111-------------------------------1122112221112-1121112-22112111111 1111111--12212-21122111222222---11-------1-1---2--1-11211222221321-12112231112212 1011
sear8    --------------------------------------------------------11--2------112---------------------111-11-11-1112121-1-111111111-1-1--21-1--1---1-------------------------------------1211- 1011
amdu2    ------------------1-1-1111122------1-----------------------------------11---------------1-1-----1-1---1-11-1111--1--1------1-----1111211------111-1111-----------1--1-1111111-111-1-111111111 110
hysa     2322333333222211121133321232322212322212111---1--1----11-111-1-23333------1-----1----1112111211222--121111111114333222233333333223222323222222331213313 223333333333222222222222222222 110
opec     ------------------1-----1---1-------1-------------------1-------------------------------11------------------------1---------1------11-------1---1-1-----11------------------------ 110
peth4    -------------------------------------------------------------------------------------------3----------1-----1---------------------11-11----11---------------------------------1 110
sef1m    -----------------1111--11-----------------------------1---12-1--11---1------1--1----11---------------------------1---1----------2111111112111112000000 1----------------------------21111 110
psarm    -----------------------------------------------------------------11--1-------------------------1---------------------11111-21---------------------------------111--1---1-1-112--1-1- 1110
SCBA     ---1----11-----------1-11111111-----------1--------------------11------1----------------------1-1111 1-11112122111113211111111111111222112121211121211122222112221113112111112121122211 1110
epca2    ------------------------------------------------------------------------------------------------------------------------------333333322-2111212212-11111112213232333332323332233 1111
isar     -------------------------------------------------------------------------------------------------------1---1-----11----11112222-11-11111111-311-111211111111111-111-121111 1111
opra     -----1111--11------------------------------------------------------------------------------------------1-------------1----1111-1--------------------------1--1--1-1-1-1-1-11- 1111
PHAR5    ----------------------------------------------------------------------------------------------------------1-----1----------------11------1--1-----11-11-1-1--1-----------1---- 1111
stli3    ----------------------------------------------------------------------------------------------------------------------------1---------------1111--1--1-----11------ 1111

         000000000000000000000000000000000000000000000000 000000000000000000000000000000000000000000000000000 000000000000011111111111111111111111111111111111111 11111111111111111111111111111111
         000000000000000000000000000000000000000000000000 000000000000000111111111111111111111111111111111111 111111111111110000000000000001111111111111111111111 11111111111111111111111111111111
         000000000000111111111111111111111111111111111111 111111111111111000000000000000000000000000000000111 111111111111111000001111111111000000000000000000000 000000111111111111111111111111
         000111111111100000000000000000000000000011111111 111111111111111100000000000111111111111111111111000 00000000001111        000111111110000000001111111111111 1111110000000000000000000000011111
             000000111110000000000000000000011111111110000000000 000000001111110111111111110000000000000011111111000 0111111111        0000011011111111000001111111 111111000000011111111111111
```

Appendix H. Two-way indicator table showing the species indicator values for the of Ward's method in canyon dataset. The groups are abbreviated as follows: A=alliance and a=association. Boxes indicate groups in which species are indicators. See Appendix B for species codes, and Figure 6 for group codes. Bolded indicator values are significant with p<0.01.

	Alliance and Association																			
	A1,A2		A2	A2	a3,a4	A1,A4		A5	A4	A4	A4	A5		A7		A8		A9	A9	A9
Species	a1,a2		a3		a4,a5	a1,a6		a7		a8	a9	a10		a11		a12		a13		a14
a1 and a2. *Acacia greggii-Prunus fasciculata* and *Baccharis sergiloides-Prunus fasciculata*																				
hysa	**55**	38	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
keanm	**29**	16	0	28	7	8	6	0	2	0	0	0	1	2	2	0	0	0	0	0
brtr	**21**	13	0	9	0	0	0	0	1	4	3	0	0	0	0	0	0	0	0	0
pest	**24**	14	0	22	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a3. *Baccharis sergiloides-Prunus fasciculata-Rhus trilobata*																				
elpa	0	25	**80**	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
putr2	5	39	**74**	26	0	0	0	0	0	0	0	0	0	0	0	0	2	9	5	0
ardr	5	42	**73**	28	0	0	0	0	0	0	0	0	0	0	2	3	1	0	0	0
pomo	0	13	**69**	33	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
brte	0	9	**46**	9	0	0	5	14	16	6	13	6	32	4	30	27	25	2	9	3
siha	0	8	**41**	22	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
mimup	0	6	**40**	6	0	11	10	0	17	3	10	8	11	6	5	0	1	0	0	0
rive	0	4	**25**	4	0	0	0	0	0	0	0	0	3	0	3	5	8	16	7	0
spcr	4	15	**22**	12	0	0	0	0	0	0	0	0	1	0	0	0	3	4	8	2
A2. *Baccharis sergiloides*																				
base	17	30	33	**86**	48	0	0	0	0	0	0	0	3	0	0	1	10	0	23	19
gumi	27	35	25	**80**	33	0	1	1	15	11	30	13	5	1	1	0	0	0	0	0
erfa2	34	47	29	**84**	28	3	3	0	1	0	0	0	1	0	1	1	1	0	2	2
lori3	24	27	16	**71**	31	22	16	0	4	0	0	0	7	0	0	0	7	1	20	15
erci6	13	18	16	**64**	34	30	40	5	19	3	2	0	6	0	0	0	0	0	0	0
yusc2	29	16	0	**63**	51	6	5	0	1	0	0	0	0	0	0	0	0	0	0	0
erli6	18	25	25	**61**	19	9	14	3	15	0	7	17	21	11	7	0	15	2	17	9
spam2	18	21	18	**60**	21	13	27	13	32	15	16	2	26	0	3	6	9	2	14	7
acgr	23	18	4	**59**	26	24	45	16	30	11	7	0	11	0	0	0	0	0	0	0
brma3	18	17	10	**59**	25	12	21	7	34	13	22	10	41	11	21	9	24	7	19	7
opapcc	23	29	18	**52**	11	13	16	1	16	4	8	4	7	0	0	0	1	0	2	1
brca3	8	16	26	**49**	22	0	0	0	1	3	2	0	12	18	24	5	23	12	10	1
acsp1	22	11	0	**47**	26	13	9	0	23	20	20	3	21	10	6	0	9	0	9	10
oece2	16	8	0	**46**	33	2	7	5	18	13	17	4	13	12	12	1	4	0	0	0
epvi	13	10	3	**41**	20	19	14	0	33	13	25	12	24	4	24	21	6	0	0	0
stpa4	36	19	0	**38**	8	16	30	13	31	22	14	0	13	1	1	0	1	1	0	0
dawr2	3	10	17	**30**	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lyan	12	7	0	**30**	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cine	11	9	2	**23**	8	0	0	0	8	11	18	7	9	0	0	0	5	2	15	10
seflm	14	8	0	**22**	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
opba2	14	8	0	**20**	9	0	0	0	2	1	4	4	2	0	0	0	2	3	5	1
opch	16	10	0	**19**	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bejua	6	3	0	**17**	15	0	4	9	1	0	0	0	0	0	0	0	0	0	0	0
latr	9	5	0	**9**	3	6	5	0	1	0	0	0	0	0	0	0	0	0	0	0

Appendix H. Continued

Species	a1,a2		a3		a4,a5	a1,a6		a7		a8	a9	a10		a11		a12		a13		a14
a4 and a5. *Baccharis sergiloides/Muhlenbergia rigens* and *Salix exigua/Baccharis sergiloides*																				
juma	1	0	0	44	94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
muri2	0	0	0	37	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
jume4	0	0	0	30	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sool	0	0	0	31	75	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0
tydo	0	0	0	30	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
tara	1	0	0	35	70	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
scba	17	9	0	50	53	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
saex	0	0	3	26	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
oepr	0	0	0	19	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
dupua2	5	2	0	30	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cyda	0	0	0	15	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
boba	1	1	0	20	35	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2
prglt	3	1	0	19	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
arpu9	1	1	0	22	29	3	9	7	17	13	12	1	15	17	10	0	6	0	2	2
caal	0	0	0	12	26	0	0	0	0	0	0	0	1	0	0	0	3	6	8	2
fecy	4	2	0	21	24	11	7	0	2	0	0	0	1	0	0	0	0	0	1	1
ercus	5	3	0	23	23	0	0	0	0	0	0	0	5	2	4	3	14	18	16	3
epca3	0	0	0	8	17	0	0	0	0	0	0	0	1	0	0	0	4	24	9	0
niob	2	1	0	13	17	0	4	10	1	0	0	0	0	0	0	0	0	0	0	0
pose	2	1	0	9	10	0	0	0	0	0	0	0	0	0	4	8	1	0	0	0
a1 and a6. *Acacia greggii/Prunus fasciculata* and *Prunus fasciculata-Purshia mexicana*																				
erin4	0	0	0	0	0	**56**	34	0	22	3	1	0	11	0	0	0	0	0	0	0
mibi8	15	16	8	29	5	**41**	31	0	16	3	2	0	5	0	0	0	0	0	0	0
dusa	1	1	0	1	0	**27**	17	0	7	0	0	0	8	15	9	0	3	0	0	0
krer	1	1	0	1	0	**26**	16	0	23	18	9	0	10	0	0	0	0	0	0	0
mefr	4	2	0	17	17	**24**	17	0	5	0	0	0	1	0	0	0	0	0	0	0
vipar	3	1	0	18	15	33	**66**	33	28	1	0	0	19	6	4	0	3	0	1	1
euin2	16	15	6	27	4	27	**48**	15	19	1	0	0	11	9	6	0	2	0	0	0
phca8	13	7	0	24	11	19	**46**	24	14	0	0	0	4	0	0	0	0	0	0	0
gaan2	2	4	8	5	0	31	**40**	8	15	0	0	0	19	38	26	0	8	0	0	0
enva	18	10	0	13	1	21	**15**	0	8	2	1	0	2	0	0	0	0	0	0	0
A6/a7. *Chilopsis linearis/Prunus fasciculata*																				
chlia	4	2	0	8	3	8	55	**64**	20	0	0	0	11	0	0	0	1	0	2	1
phcr1	0	0	0	0	0	0	24	**64**	17	4	2	0	9	0	0	0	0	0	0	0
brlom	0	0	0	0	0	0	14	**46**	35	35	19	0	26	11	7	0	2	0	0	0
asmo5	2	1	0	8	7	0	13	**32**	4	0	0	0	1	0	0	0	0	0	0	0
erpu8	2	1	0	5	3	0	4	**11**	5	4	2	0	2	0	0	0	0	0	0	0
A4. *Prunus fasciculata*																				
opph	0	0	0	0	0	18	32	15	**71**	20	38	29	70	17	23	9	15	0	4	4
pume	0	0	0	0	0	19	30	10	**56**	18	26	12	49	4	24	25	6	0	0	0
prfa	20	23	16	42	5	14	30	15	**50**	17	29	13	39	6	17	10	10	0	4	2
crust	1	0	0	3	3	1	8	11	**36**	20	34	18	18	0	1	3	0	0	0	0
samo3	19	13	1	25	3	29	36	6	**38**	12	15	5	15	1	1	0	0	0	0	0
gaco5	0	0	0	0	0	0	6	19	**35**	38	32	4	17	0	0	0	0	0	0	0
ecen	3	4	6	23	14	27	28	2	**30**	13	12	1	14	1	3	1	1	0	0	0

Appendix H. Continued

Species	a1,a2		a3		a4,a5	a1,a6		a7		a8	a9	a10		a11		a12		a13		a14
a8. *Prunus fasciculata* undifferentiated																				
trra5	0	0	0	0	0	0	1	4	22	50	28	0	28	9	4	0	8	0	7	8
agutg	0	0	0	0	0	0	0	0	18	47	31	0	13	0	3	7	1	0	0	0
same1	3	6	10	12	2	1	6	7	32	40	36	1	14	0	0	0	0	0	1	0
amer	3	2	0	2	0	0	0	0	10	33	21	0	6	0	0	0	1	0	2	2
a9. *Prunus fasciculata-Rhus trilobata*																				
thmo	6	3	0	4	0	3	8	6	52	29	52	29	34	4	11	6	3	0	0	0
mipu6	2	10	33	10	0	0	0	0	21	13	40	22	14	1	8	7	2	0	0	0
trmu	0	0	0	0	1	1	3	2	28	17	29	16	29	15	14	2	6	0	1	1
arma3	0	0	0	0	0	3	2	0	16	14	16	4	15	15	8	0	2	0	0	0
A5/a10. *Salvia dorrii*																				
cora	1	1	0	2	1	0	0	0	17	0	34	89	7	0	0	0	0	0	0	0
sado4	1	4	13	5	0	3	3	0	41	9	53	59	17	0	0	0	0	0	0	0
hemun	0	0	0	0	0	0	0	0	12	0	19	53	13	0	9	23	3	0	0	0
caan7	0	0	0	0	0	0	0	0	17	2	31	50	9	0	0	0	0	0	0	0
erco1	0	0	0	0	0	0	0	0	7	0	12	43	13	0	0	0	6	30	15	0
mesc2	0	0	0	0	0	10	8	0	18	0	10	37	13	5	3	0	1	0	0	0
aslef	0	0	0	0	0	0	0	0	8	0	13	36	11	0	11	25	3	0	0	0
esvid	0	0	0	0	0	0	0	0	18	6	31	34	13	0	3	7	1	0	0	0
gusa2	0	0	0	0	0	20	32	20	36	9	9	4	77	7	13	10	41	16	44	16
yuba	0	3	18	4	0	13	26	14	53	16	29	18	79	16	30	16	35	7	22	8
pepap	2	7	23	8	0	11	26	13	52	16	29	16	54	18	41	18	16	0	1	1
rhtr	3	9	22	28	10	3	2	0	23	16	30	15	50	14	25	12	41	11	33	13
arlu	5	9	17	38	18	13	19	7	26	16	13	1	40	15	12	1	28	11	30	11
phhe4	1	4	13	7	0	3	2	0	16	21	19	1	32	22	18	1	22	4	13	6
A7/a11. *Quercus chrysolepis/Rhamnus ilicifolia*																				
lopa	0	0	0	0	0	0	0	0	0	0	0	0	11	83	45	0	21	0	0	0
erut	0	0	0	0	0	8	5	0	2	0	0	0	17	83	47	0	19	0	0	0
lesam	0	0	0	0	0	0	0	0	0	0	0	0	17	81	58	3	33	3	1	0
chfe	0	0	0	0	0	0	0	0	3	6	4	0	15	70	38	0	15	0	0	0
henac	0	0	0	0	0	2	1	0	15	25	16	0	23	53	29	0	9	0	0	0
quch2	0	0	2	0	0	0	0	0	0	0	0	0	12	55	29	0	24	9	3	0
rhcri	3	5	6	5	0	3	2	0	1	0	0	0	20	55	42	2	34	11	6	0
rhtou	1	8	29	8	0	0	0	0	0	0	0	0	5	49	35	0	13	0	0	0
arpe2	0	0	0	0	0	0	1	4	0	0	0	0	28	47	20	0	46	28	28	6
agde	1	1	0	1	0	10	7	0	3	0	0	0	10	46	27	0	10	0	0	0
lepu	2	1	0	1	0	0	0	0	0	0	0	0	4	42	24	0	10	0	0	0
moli3	4	2	0	3	0	2	2	0	1	0	0	0	8	39	36	3	13	0	0	0
chnan	0	0	0	0	0	0	2	5	3	1	1	0	13	32	31	4	12	0	0	0
maana	0	0	0	0	0	9	14	5	10	2	1	0	15	29	17	0	5	0	0	0
epne	10	5	0	13	3	0	4	13	5	4	3	0	7	28	17	0	5	0	0	0
arjo2	0	0	0	0	0	0	0	0	4	11	7	0	9	23	12	0	4	0	0	0
gafl	0	0	2	0	0	0	0	0	1	0	1	3	24	21	75	59	37	0	0	0
cein7	0	0	0	0	0	0	0	0	2	5	3	0	17	36	47	13	19	0	0	0
fran	0	0	0	0	0	0	0	0	0	0	0	0	21	32	48	23	42	2	6	4
acpa	0	1	2	2	0	3	2	0	7	5	5	1	32	25	45	23	32	10	6	0
erhes	0	0	0	0	0	1	3	3	11	12	8	0	30	24	42	19	19	0	1	1
cali4	0	0	2	1	0	0	0	0	9	7	15	10	40	24	40	22	39	9	13	4

Appendix H. Continued

Species	a1,a2		a3	a4,a5		a1,a6		a7		a8	a9	a10		a11		a12		a13		a14
A8/a12. *Pinus monophylla/Garrya flavescens*																				
hyco	0	0	0	0	0	0	0	0	0	0	0	0	11	0	30	**73**	21	4	1	0
phst	0	0	0	0	0	0	0	0	5	0	8	24	17	0	23	**58**	13	3	1	0
artr2g	0	0	0	0	0	0	0	0	2	0	3	9	17	7	48	**54**	19	0	0	0
sylo	0	0	0	0	0	0	0	0	1	0	1	2	11	2	34	**51**	15	0	0	0
ermi	0	0	0	0	0	0	0	0	4	0	6	16	11	0	21	**48**	7	0	0	0
brobl	0	0	0	0	0	0	0	0	4	0	7	20	9	0	12	**29**	4	0	0	0
crfl	0	0	0	0	0	0	0	0	4	0	7	20	9	0	12	**29**	4	0	0	0
ectr	2	1	0	3	1	1	1	0	11	9	14	6	28	5	23	**28**	21	20	7	0
chde	0	0	0	0	0	0	0	0	1	0	1	5	11	0	9	**25**	13	4	6	2
pofel	0	0	0	0	0	1	1	0	5	5	5	1	49	16	33	28	**59**	25	33	10
gapa4	0	0	0	0	0	0	0	0	0	0	0	0	30	37	44	19	**58**	15	18	6
pimo	1	5	22	9	1	0	0	0	8	3	14	18	46	16	39	27	**55**	20	30	7
oper	1	9	35	10	0	0	0	0	1	0	1	4	26	7	29	28	**51**	21	32	8
elele	3	5	9	15	4	4	3	0	12	10	12	3	46	19	36	19	**50**	15	30	11
lichen	9	15	22	28	4	0	0	0	4	2	5	3	33	12	34	24	**53**	14	34	14
peea	0	0	0	0	0	2	1	0	0	0	0	0	28	25	38	21	**46**	16	14	3
juos	0	1	6	1	0	0	0	0	5	2	7	8	32	19	29	14	**37**	15	16	3
moss	1	4	15	27	19	5	3	0	9	5	7	3	31	14	21	7	**36**	10	28	12
agheg	0	0	0	0	0	0	0	0	0	0	0	0	13	3	15	20	**25**	15	11	1
heru	0	0	0	0	0	0	0	0	0	0	0	0	9	5	10	8	**17**	21	7	0
a13. *Quercus turbinella-Pinus monophylla*																				
woor	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	17	**50**	31	2
asnu3	0	1	5	3	1	0	0	0	0	0	0	0	8	0	0	0	19	**48**	40	5
sivea	0	0	0	0	0	0	0	0	0	0	0	0	15	13	13	5	29	**48**	16	0
asasa	0	0	0	0	0	0	0	0	2	6	3	0	19	3	11	16	22	**40**	14	0
A9. *Quercus turbinella*																				
qutu	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	54	52	**100**	48
bocu	0	0	0	0	0	0	0	0	0	2	1	0	23	0	0	0	38	23	**73**	48
pemu	0	0	0	1	1	0	0	0	0	0	0	0	18	0	0	0	38	39	**73**	34
fapa	0	0	0	0	0	0	0	0	10	0	17	53	47	1	3	5	41	29	**64**	20
erwr	1	12	42	22	5	0	0	0	0	0	0	0	10	1	1	0	29	30	**55**	17
gamu	0	1	11	2	0	0	0	0	1	4	2	0	22	2	3	2	34	40	**46**	10
agvi	0	0	0	6	11	0	0	0	0	0	0	0	5	0	0	0	14	15	**30**	13
a14. *Quercus turbinella/Baccharis sergiloides*																				
erdi	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	21	0	38	**63**
brdi	0	0	3	5	5	2	1	0	0	0	0	0	11	0	0	0	21	0	47	**61**

Appendix I. Two-way indicator table showing the species indicator values for the Twinspan groups in canyon dataset. The groups are abbreviated as follows: A=alliance and a=association. Boxes indicate groups in which species are indicators. See Appendix B for species codes and Figure 6 for group codes. Bolded indicator values are significant with p<0.01.

	Alliance and Association																									
		A2, A3		A2	A1,A4,A6			A4		A2		A2			A4				A8	A8	A7				A9	
Species		a4,a5			a2	a1,a6,a7		a8		a2		a3			a10	a9,a10,a12			a12		a11		a14			a13
prglt	**76**	23	3	26	4	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
niob	**75**	16	1	17	3	1	1	0	1	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
pomo	**55**	14	2	12	0	0	0	0	10	0	44	37	21	0	0	0	0	0	0	0	0	0	0	0	0	0
dawr2	**53**	15	3	25	7	0	0	0	2	0	9	9	19	0	0	0	0	0	0	0	0	0	0	0	0	0
phca8	**50**	11	2	30	26	14	13	0	11	0	0	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0
agvi	45	8	1	5	0	0	0	0	0	0	0	0	2	11	0	0	0	0	0	0	0	0	8	20	25	19
epne	37	3	0	10	11	3	8	6	7	0	0	0	16	4	0	0	0	7	0	13	16	0	0	0	0	0
latr	30	2	0	12	15	1	1	0	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
asmo5	27	8	1	10	4	4	4	0	3	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
caal	22	20	10	13	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0	0	0	0	6	13
erpu8	19	2	0	2	0	1	4	3	9	19	6	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
cine	19	6	1	15	10	0	1	7	4	5	3	1	17	11	9	3	0	2	1	0	0	1	8	9	11	3
a4 and a5. *Baccharis sergiloides/Muhlenbergia rigens* and *Salix exigua/Baccharis sergiloides*																										
juma	45	**75**	36	54	1	0	0	2	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0
muri2	11	**75**	63	53	1	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0
jume4	14	**73**	57	42	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
tydo	18	**73**	50	42	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
tara	47	**65**	29	38	0	0	0	2	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	1	2
sool	52	**53**	23	41	2	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	1	2
saex	22	**48**	27	30	0	0	0	0	0	0	2	2	17	0	0	0	0	0	0	0	0	0	0	0	0	0
arpu9	20	**27**	12	24	2	4	8	3	7	0	0	0	26	11	2	1	0	11	5	14	9	5	3	0	1	0
bejua	24	24	11	23	3	1	1	0	1	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
oepr	0	45	**56**	26	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
boba	0	43	**48**	26	0	0	0	0	0	0	0	0	12	1	0	0	0	0	0	0	0	7	3	0	1	0
cyda	0	36	**44**	21	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
epca3	0	13	18	8	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0	7	15

Appendix I. Continued

Species		a4,a5			a2	a1,a6,a7		a8		a2		a3			a10	a9,a10,a12			a12		a11		a14			a13
A2. Baccharis sergiloides																										
yusc2	9	41	37	87	49	1	1	0	1	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0
scba	33	39	20	59	18	0	0	0	0	8	1	0	31	0	0	0	0	0	0	0	0	0	0	0	1	1
base	19	29	16	53	19	0	0	0	6	8	25	17	47	8	0	0	0	0	0	0	0	11	20	13	21	3
dupua2	19	25	15	42	17	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
lyan	17	22	14	42	20	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
pest	0	11	16	32	22	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
fecy	15	21	12	26	6	2	2	0	1	0	0	0	19	0	0	0	0	0	0	0	0	0	2	6	1	0
opch	0	6	8	26	25	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
mefr	18	9	4	22	17	5	4	0	4	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0
a2. Baccharis sergiloides-Prunus fasciculata																										
keanm	0	2	3	37	62	2	1	0	1	0	0	0	24	0	0	0	0	0	0	1	2	0	0	0	0	0
brtr	0	0	0	12	32	0	1	7	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
opba2	12	3	1	22	31	0	0	2	0	0	0	0	13	3	5	1	0	1	0	0	0	0	0	0	3	6
enva	15	1	0	12	21	4	11	10	10	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0
pose	0	2	2	11	13	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	2	4
a1, a6, and a7. *Acacia greggii-Prunus fasciculata, Prunus fasciculata-Purshia mexicana, Chilopsis linearis/Prunus fasciculata*																										
phcr1	0	0	0	0	0	36	25	0	17	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
erin4	0	0	0	0	0	23	31	7	22	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
brlom	0	0	0	0	0	11	22	12	18	0	0	0	10	6	0	2	3	11	4	12	8	0	0	0	0	0
dusa	0	0	0	0	0	9	14	5	11	0	0	0	6	2	0	0	0	4	0	9	14	0	0	0	0	0
a8. *Prunus fasciculata* undifferentiated																										
same1	5	1	0	4	3	2	15	33	23	0	5	5	23	5	2	3	1	5	8	3	0	1	1	0	0	0
amer	0	0	0	0	0	0	9	31	17	24	6	0	10	1	0	0	0	0	0	0	0	3	3	0	2	0
arma3	0	0	0	0	0	1	11	29	9	0	0	0	5	5	0	3	3	8	0	7	9	0	0	0	0	0
trra5	0	0	0	0	0	1	12	25	10	0	0	0	6	13	0	0	0	7	10	13	4	22	15	0	7	0
gaco5	0	0	0	0	0	2	15	23	12	0	0	0	7	4	7	9	3	7	4	2	0	0	0	0	0	0
trmu	7	1	0	0	0	2	13	19	11	0	0	0	8	14	3	17	11	19	0	6	7	0	1	3	1	0
gaan2	0	0	0	0	0	16	14	0	30	30	18	5	16	7	0	0	0	12	0	20	30	0	0	0	0	0
krer	0	0	0	0	0	5	27	26	30	18	4	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
a2. Baccharis sergiloides-Prunus fasciculata																										
seflm	0	20	14	15	0	0	0	0	3	69	13	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
spcr	0	0	0	0	0	0	0	0	10	56	38	9	6	2	0	0	0	0	0	0	0	3	2	0	6	2

Appendix I. Continued

Species	a4,a5				a2	a1,a6,a7		a8		a2		a3			a10	a9,a10,a12			a12		a11		a14			a13
hysa	0	1	1	11	15	0	0	2	4	52	8	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
ardr	0	0	0	0	0	0	0	2	29	43	83	43	16	0	0	0	0	0	0	0	0	0	0	0	1	2
putr2	0	0	0	1	1	0	0	0	19	38	74	46	15	1	0	0	0	0	0	0	0	0	0	0	4	5
mimup	0	0	0	0	0	3	5	2	19	0	24	25	10	7	18	5	0	12	2	7	4	0	0	0	0	0
a3. *Baccharis sergiloides-Prunus fasciculata-Rhus trilobata*																										
elpa	0	0	0	0	0	0	0	0	17	0	57	80	10	0	0	0	0	0	0	0	0	0	0	0	0	0
siha	0	11	12	9	0	0	0	0	6	0	26	39	14	0	0	0	0	0	0	0	0	0	0	0	0	0
acgr	20	22	10	47	28	16	30	18	41	10	8	2	88	0	0	0	0	0	0	0	0	1	0	0	0	0
erci6	22	25	12	41	16	11	17	5	35	15	20	9	76	0	0	0	1	0	0	0	0	0	0	0	0	0
spam2	9	16	9	33	16	9	16	9	33	9	16	9	67	17	0	6	9	7	5	1	0	2	8	9	11	3
gumi	12	23	12	50	23	0	4	12	20	18	27	12	64	4	5	6	2	6	1	1	0	0	0	0	0	0
brma3	10	19	11	37	19	7	13	8	23	5	9	5	60	40	7	11	6	22	7	11	6	5	9	5	18	9
erfa2	4	18	14	54	34	1	1	1	11	18	27	18	57	1	0	0	0	0	0	0	0	4	2	0	3	1
prfa	0	3	3	18	20	12	22	13	41	13	18	9	57	25	9	16	9	24	8	9	3	2	3	0	4	1
lori3	14	22	14	50	28	4	4	1	12	3	11	9	56	6	0	0	0	0	0	0	0	14	16	6	15	2
opapcc	14	8	3	30	24	5	8	2	25	22	24	9	55	2	6	2	0	1	0	0	0	4	2	0	1	0
stpa4	16	6	2	30	35	9	20	16	25	16	3	0	54	3	0	0	1	3	4	3	0	0	0	0	0	1
erli6	9	13	7	30	16	5	5	0	18	9	20	13	47	25	12	7	1	11	0	4	6	5	12	9	14	3
oece2	14	28	14	38	11	3	11	14	14	14	2	0	47	8	2	7	5	11	0	4	6	1	1	0	0	0
acspl	11	21	11	42	23	3	10	11	11	3	0	0	46	18	1	3	2	10	3	8	5	11	15	5	7	0
mibi8	0	8	8	20	15	12	18	14	25	0	5	6	45	0	0	0	0	0	0	0	0	0	0	0	0	0
euin2	0	1	1	11	17	21	20	1	36	26	14	4	44	1	0	0	0	2	0	4	6	0	0	0	0	0
vipar	19	24	13	19	2	39	30	0	24	0	0	0	44	3	0	0	0	1	0	3	5	5	3	0	1	0
epvi	3	16	12	36	22	5	10	9	13	0	2	2	43	19	5	19	17	26	12	10	3	0	0	0	0	0
arlu	0	12	11	15	3	8	13	9	27	9	15	9	43	35	0	1	2	10	2	10	9	9	15	9	30	15
samo3	0	1	1	16	27	16	15	1	24	21	6	1	39	5	0	5	8	8	5	3	1	0	0	0	0	0
ecen	20	9	2	11	3	8	20	13	29	5	8	3	38	4	2	3	1	4	1	2	1	0	0	0	0	1
chlia	11	6	2	6	1	22	21	0	22	11	2	0	26	1	0	0	0	0	0	0	0	5	3	0	1	0
brca3	14	15	8	22	6	0	0	2	6	3	17	14	24	24	0	0	0	11	8	17	11	0	0	2	14	20
pimo	0	0	0	1	2	0	0	0	3	0	9	10	4	76	11	18	11	42	18	21	10	4	10	11	34	23
fapa	0	0	0	0	0	0	0	0	0	0	0	0	0	69	29	40	20	20	0	0	0	19	27	12	56	26
pofel	0	0	0	0	0	0	0	0	0	0	0	0	0	67	0	5	7	27	26	25	9	1	11	21	41	34
rhtr	0	5	4	9	3	1	5	9	13	1	12	11	22	64	11	15	7	31	11	16	8	9	17	11	34	16
elele	0	1	1	5	5	1	4	8	7	0	4	4	13	60	1	8	8	27	12	20	12	7	14	12	34	20

Appendix I. Continued

Species		a4,a5			a2	a1,a6,a7		a8		a2		a3			a10	a9,a10,a12			a12		a11		a14			a13
yuba	0	0	0	0	0	12	20	9	31	0	9	9	18	**60**	15	21	9	38	12	18	9	5	12	9	24	12
cali4	0	0	0	0	0	0	0	1	1	0	1	1	1	**59**	2	20	20	50	20	29	14	0	3	9	13	12
lichen	3	1	1	8	10	0	1	0	6	3	13	11	14	**57**	1	4	4	21	13	16	7	11	18	11	39	20
gusa2	0	0	0	0	0	16	15	1	13	0	0	0	8	**54**	2	10	10	18	9	9	4	16	26	16	42	19
juos	0	0	0	0	0	0	0	0	0	0	2	3	0	**50**	0	7	11	34	27	28	12	0	2	8	16	17
oper	0	0	0	0	0	0	0	0	6	17	28	17	4	**49**	0	7	11	16	4	7	4	4	9	7	39	28
gapa4	0	0	0	0	0	0	0	0	0	0	0	0	0	**44**	0	1	1	23	9	29	25	0	5	16	21	19
acpipa	6	0	0	1	1	1	1	0	1	0	1	1	2	**43**	0	6	9	35	24	33	17	0	0	0	10	21
moss	3	17	12	11	0	2	2	0	8	3	11	8	19	**43**	1	1	0	15	12	17	8	7	15	12	30	15
brte	0	0	0	0	0	2	3	0	19	3	30	27	11	**39**	1	13	15	28	15	11	3	1	4	5	13	8
ectr	0	0	0	2	3	0	1	1	1	0	0	0	2	**37**	3	17	17	33	27	16	3	0	0	0	7	14
arpe2	0	0	0	0	0	0	0	0	0	0	0	0	0	**35**	0	0	0	9	0	16	30	0	5	19	30	33
peea	0	0	0	0	0	0	0	0	0	0	0	0	0	**35**	0	1	2	14	3	16	19	3	5	5	23	21
phhe4	4	0	0	1	1	1	5	11	12	4	11	6	10	**32**	0	5	6	20	4	16	12	4	6	2	12	6
fran	0	0	0	0	0	0	0	0	0	0	0	0	0	**31**	0	6	9	26	2	21	26	0	1	4	7	7
erco1	0	0	0	0	0	0	0	0	0	0	0	0	0	**19**	10	17	14	7	0	0	0	0	0	0	12	23
agheg	0	0	0	0	0	0	0	0	0	0	0	0	0	**19**	0	0	0	7	23	12	3	0	0	0	12	25
hyco	0	0	0	0	0	0	0	0	0	0	0	0	0	**16**	0	3	4	9	25	7	0	0	0	0	7	13
A5/a10. *Salvia dorrii*																										
caan7	0	0	0	0	0	0	0	0	0	0	0	0	0	13	**80**	30	0	22	5	2	0	0	0	0	0	0
mesc2	0	0	0	0	0	2	3	0	2	0	0	0	1	9	**74**	23	0	16	0	2	2	0	0	0	0	0
cora	0	1	0	1	0	0	0	0	0	9	2	0	1	13	**62**	49	6	22	0	0	0	0	0	0	0	0
sado4	0	0	0	0	0	1	10	23	22	4	11	5	12	9	**43**	36	6	15	0	0	0	0	0	0	0	0
a9, a10, a12. *Prunus fasciculata-Rhus trilobata, Salvia dorrii, Pinus monophylla/Garrya flavescens*																										
hemun	0	0	0	0	0	0	0	0	0	0	0	0	0	19	30	**75**	44	33	0	0	0	0	0	0	0	0
aslef	0	0	0	0	0	0	0	0	0	0	0	0	0	16	10	**63**	56	28	0	0	0	0	0	0	0	0
thmo	0	0	0	2	6	4	16	21	15	0	0	0	14	21	21	**42**	21	35	5	7	2	0	0	0	0	0
esvid	0	0	0	0	0	0	3	11	2	0	0	0	1	9	30	**40**	11	16	0	0	0	0	0	0	0	0
phst	0	0	0	0	0	0	0	0	0	0	0	0	0	25	23	**40**	19	33	13	4	0	0	0	0	1	2
mipu6	0	0	0	0	0	0	3	14	22	23	35	14	12	13	10	**37**	23	22	0	0	1	0	0	0	0	0
crfl	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	50	**80**	22	0	0	0	0	0	0	0	0
brobl	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	50	**80**	22	0	0	0	0	0	0	0	0
ermi	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	24	**33**	28	23	7	0	0	0	0	0	0

Appendix I. Continued

Species		a4,a5			a2	a1,a6,a7		a8		a2		a3			a10	a9,a10,a12			a12		a11		a14			a13
opph	0	0	0	0	0	14	24	8	22	0	0	0	12	41	21	36	15	**47**	10	19	9	3	8	6	4	0
pepap	0	0	0	0	0	11	21	12	43	12	23	12	24	36	12	23	12	**45**	12	23	12	3	2	0	2	0
artr2g	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	30	44	**44**	14	16	6	0	0	0	0	0
gafl	0	0	0	0	0	0	0	0	0	0	1	1	0	36	0	16	25	**41**	10	25	19	0	1	2	3	3
pume	0	0	0	0	1	16	24	8	21	0	0	0	13	21	2	30	32	**37**	18	14	3	0	0	0	0	0
A8/a12. *Pinus monophylla/Garrya flavescens*																										
agutg	0	0	0	0	0	0	7	27	6	0	0	0	3	5	0	0	0	9	**42**	18	0	0	0	0	0	0
sylo	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	10	12	28	**31**	18	1	0	0	0	0	0
chde	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	3	3	9	**21**	7	0	0	3	9	7	3
crust	0	1	0	3	4	5	10	6	9	0	0	0	11	9	16	10	1	15	21	6	0	0	0	0	0	0
A8. *Pinus monophylla*																										
cein7	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	44	60	**80**	27	0	0	0	0	0
chfe	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	39	19	**70**	52	0	0	0	0	0
henac	0	0	0	0	0	2	7	8	5	0	0	0	3	15	0	0	0	27	13	**52**	36	0	0	0	0	0
chnan	0	0	0	0	0	1	1	0	1	0	0	0	0	14	0	0	0	25	20	**45**	27	0	0	0	0	0
arjo2	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	22	30	**40**	13	0	0	0	0	0
erhes	0	0	0	0	0	1	5	6	4	0	0	0	2	24	0	5	6	34	22	**36**	17	0	0	0	1	2
moli3	0	0	0	3	8	1	0	0	0	0	0	0	2	11	0	0	0	18	5	**31**	35	0	0	0	0	0
agde	0	0	0	1	2	3	2	0	2	0	0	0	3	8	0	0	0	14	0	**25**	46	0	0	0	0	0
A7/a11. *Quercus chrysolepis/Rhamnus ilicifolia*																										
erut	0	0	0	0	0	3	2	0	2	0	0	0	1	15	0	0	0	26	0	50	**85**	0	0	0	0	0
lopa	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	28	0	50	**83**	0	0	0	0	0
lesam	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	24	0	43	**80**	0	0	0	4	8
quch2	0	0	0	0	0	0	0	0	0	0	1	1	0	18	0	0	0	16	0	27	**51**	0	0	0	4	7
rhcri	0	0	0	1	2	1	1	0	3	6	6	4	4	27	0	0	0	15	0	24	**46**	0	0	0	12	24
lepu	0	0	0	1	4	0	0	0	0	0	0	0	0	7	0	0	0	13	0	21	40	0	0	0	0	0
rhtou	0	0	0	0	0	0	0	0	6	14	29	16	3	10	0	0	0	18	0	25	38	0	0	0	0	0
maana	0	0	0	0	0	15	11	0	9	0	0	0	5	5	0	0	0	8	0	16	29	0	0	0	0	0
a14. *Quercus turbinella/Baccharis sergiloides*																										
brdi	38	3	0	2	0	0	0	0	1	0	1	1	3	17	0	0	0	0	0	0	0	25	**62**	25	40	1
erdi	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	19	**46**	34	36	3

Appendix I. Continued

Species		a4,a5			a2	a1,a6,a7		a8		a2		a3			a10	a9,a10,a12			a12		a11		a14			a13
A9. *Quercus turbinella*																										
qutu	0	0	0	0	0	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	37	54	33	93	39
pemu	0	1	1	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	11	34	43	67	34
bocu	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	0	0	0	3	1	0	40	48	18	66	21
gamu	0	0	0	0	0	0	0	0	1	0	4	5	0	36	0	0	0	3	8	4	1	2	9	15	53	50
erwr	0	1	1	3	2	0	0	1	5	0	18	24	9	23	0	0	0	0	0	0	1	24	26	11	47	18
asnu3	0	1	1	1	0	0	0	0	0	0	2	3	1	15	0	0	0	0	0	0	0	0	7	29	35	30
a13. *Quercus turbinella-Pinus monophylla*																										
sivea	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	3	0	4	11	0	0	0	27	56
woor	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	29	57
asasa	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	6	10	14	15	8	2	0	0	0	14	29
ercus	0	16	20	23	7	0	0	0	0	0	0	0	11	11	0	0	0	0	0	1	1	0	1	5	19	27
rive	0	0	0	0	0	0	0	0	3	0	11	19	2	6	0	0	0	0	0	0	0	0	0	0	15	26
heru	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	5	9	8	4	0	0	0	8	17

Appendix J. Two-way indicator table showing the species indicator values for the groups of Ward's method in wash/arroyo dataset. The groups are abbreviated as follows: A=alliance and a=association. Boxes indicate groups in which species are indicators. See Appendix B for species codes and Figure 11 for group codes. Bolded indicator values are significant with p<0.01.

Species	Indicator values for groups																	
	A1,A2		A3,A4			A4		A1,A:	A1		A3	A6		A3,A5		A3		A7
Species	a1,a2		a3,a4		a5,a6			a7,a8	a9		a10	a14		a11,a12		a13		a15
gaco5	**52**	14	0	0	0	0	19	1	0	5	3	0	0	0	0	0	0	0
enva	**51**	32	0	2	3	6	34	11	15	7	1	10	35	16	11	0	0	0
ecen	**49**	25	2	1	1	6	43	13	3	17	10	0	0	0	0	0	0	0
lyan	**44**	32	1	12	19	9	22	1	1	0	0	0	0	0	11	3	14	7
chal11	**48**	17	0	0	0	1	10	4	0	0	0	0	11	15	4	0	0	0
psco2g	**46**	10	0	0	1	0	16	0	33	8	0	0	5	6	1	0	0	0
mipu6	**37**	32	2	3	3	8	22	13	0	0	0	0	0	0	0	0	0	0
orco4	**36**	9	0	0	0	0	6	0	0	0	0	0	1	1	0	0	0	0
trmu	**36**	24	0	0	1	7	35	21	15	10	2	0	0	0	0	0	0	0
esvid	**35**	29	0	0	0	7	20	28	0	0	0	0	0	0	0	0	0	0
opba2	**32**	13	0	0	0	2	20	10	1	9	5	3	2	0	2	0	1	0
moss	**30**	15	2	1	0	1	9	2	0	0	0	5	3	0	1	0	0	0
yuba	**27**	19	0	0	0	5	21	21	2	3	1	0	0	0	0	0	0	0
lefrf	**23**	14	5	2	0	2	8	2	0	0	0	1	1	1	3	0	2	1
alin	**18**	7	0	1	3	1	12	0	0	6	5	0	1	2	0	0	0	0
sado4	37	**73**	11	18	18	42	71	34	28	6	0	0	3	2	1	0	0	0
amer	14	**71**	25	29	16	49	47	36	0	0	0	7	29	17	7	0	0	0
gumi	42	**56**	8	6	3	22	41	41	0	0	0	0	0	0	0	0	0	0
same1	44	**58**	5	12	13	24	47	25	5	2	0	2	2	0	4	0	3	2
yubr	45	**48**	0	3	8	14	33	29	0	0	0	0	0	0	0	0	0	0
adco	33	**41**	3	12	13	17	24	16	0	0	0	4	5	1	24	1	22	15
mupo2	27	**37**	0	8	18	15	28	14	2	0	0	0	0	0	0	0	0	0
krer	24	**31**	0	4	10	13	29	17	11	2	0	1	1	0	0	0	0	0
mesp2	8	9	0	0	1	3	8	8	4	1	0	0	0	0	0	0	0	0
lyco2	0	10	4	**20**	15	12	6	0	0	0	0	2	1	0	1	1	0	0
erpl3	0	7	1	16	**17**	9	4	0	0	0	0	1	0	0	4	3	4	1
prfa	1	42	34	23	7	**51**	42	35	3	4	2	1	0	0	0	0	0	0
acgr	11	41	14	21	18	36	**68**	22	27	35	15	1	7	6	12	1	6	3
pepap	26	23	1	2	3	12	**62**	23	30	49	21	0	2	1	1	0	0	0
erpu8	16	22	1	5	9	14	**54**	16	18	43	22	0	8	9	2	0	0	0
opapcc	32	32	6	7	5	15	**56**	16	13	28	14	8	6	0	2	0	0	0
epne	38	36	0	9	18	15	**53**	15	0	19	18	2	4	1	1	0	0	0
stpa4	26	27	7	7	5	12	**45**	10	18	30	13	6	24	17	19	1	4	2
spam2	28	24	5	6	4	10	**42**	9	21	26	9	2	17	16	11	0	1	1
erin4	36	18	0	2	4	4	**42**	5	11	39	20	11	18	5	8	0	0	0
arpu9	34	16	0	1	2	4	**36**	7	29	20	4	0	0	0	0	0	0	0
niob	13	5	10	2	0	1	**12**	0	0	8	7	0	1	2	0	0	0	0
brte	1	5	1	0	0	4	**8**	13	0	3	3	0	0	0	0	0	0	0

Appendix J. Continued

Species	a1,a2		a3,a4		a5,a6			a7,a8	a9		a10	a14		a11,a12		a13		a15
crust	3	10	4	4	2	9	22	12	1	22	21	11	6	0	15	0	7	7
cora	1	20	1	0	0	21	14	**52**	0	0	0	0	0	0	0	0	0	0
mimup	0	22	3	2	1	29	15	**51**	0	0	0	0	0	0	0	0	0	0
fapa	0	13	0	0	0	18	9	**50**	0	0	0	0	0	0	0	0	0	0
opph	0	8	0	0	0	13	21	**43**	0	15	20	0	0	0	0	0	0	0
rhtr	0	13	3	1	0	19	12	**41**	0	1	1	0	0	0	0	0	0	0
acsp1	10	23	1	1	1	16	26	**37**	13	4	0	0	0	0	0	0	0	0
cine	12	15	1	0	0	6	13	**20**	3	1	0	0	0	0	0	0	0	0
oper	2	12	5	1	0	10	8	**20**	0	0	0	0	0	0	0	0	0	0
erli6	0	6	3	0	0	8	9	**15**	12	4	0	0	0	1	0	1	0	0
caan7	5	9	1	0	0	5	9	**14**	4	1	0	0	0	0	0	0	0	0
epvi	0	2	0	0	0	2	15	5	**78**	28	1	0	1	1	0	0	0	0
yusc2	31	21	4	8	9	8	38	1	**40**	20	3	0	0	0	2	0	2	2
thmo	13	18	2	1	1	8	23	17	**35**	8	0	6	18	7	6	0	0	0
fecy	0	0	1	0	0	0	6	0	**25**	17	3	1	0	0	0	0	0	0
plri3	4	2	0	1	1	0	5	0	**11**	5	0	3	4	1	1	0	0	0
vipar	0	0	0	0	0	0	23	0	62	**74**	20	0	8	12	5	0	0	0
gusa2	0	0	0	0	0	0	21	0	54	**74**	28	0	3	5	1	0	0	0
oece2	27	11	0	0	0	3	44	12	7	**47**	32	0	0	0	0	0	0	0
brma3	21	20	8	4	1	9	41	11	28	**39**	15	3	18	16	38	11	18	7
phca8	0	10	9	11	8	15	28	4	10	**27**	19	0	1	2	2	1	1	0
pogr5	0	0	0	0	0	0	7	0	22	**25**	8	0	0	1	0	0	0	0
lori3	0	0	4	1	0	1	3	0	4	8	4	1	0	0	3	3	2	1
enfa	0	0	0	0	0	0	17	0	0	55	**74**	0	0	0	0	0	0	0
bejua	1	0	0	0	0	0	20	0	3	67	**68**	1	4	4	2	0	0	0
phcr1	0	1	0	0	0	1	15	3	0	41	**49**	14	5	0	2	0	0	0
chlia	0	7	10	5	1	10	27	14	0	39	**47**	0	7	16	14	26	5	0
base	0	0	4	1	0	0	9	0	0	21	**28**	0	0	0	0	0	0	0
krgr	1	1	4	1	0	1	4	0	4	8	3	**35**	35	8	24	1	3	2
psarm	0	0	0	0	0	0	0	0	15	3	0	**23**	13	0	21	0	8	7
sear8	0	1	8	2	0	1	2	0	11	2	0	32	**52**	20	32	0	3	2
erfa2	1	15	10	10	5	13	19	5	35	9	0	15	**41**	21	21	1	2	1
mibi8	22	14	3	2	0	4	25	5	19	19	5	25	**31**	5	14	1	1	0
cupa	0	0	0	0	0	0	0	0	0	0	0	9	**19**	13	12	0	1	1
chpa	7	4	3	2	0	1	4	0	3	1	0	0	39	**64**	18	0	1	0
phhe4	11	10	3	1	0	2	6	6	1	0	0	0	31	**48**	11	0	0	0
brin	14	8	0	3	4	2	7	0	0	1	1	0	13	**21**	20	9	9	2
dawr2	0	4	1	7	7	4	2	0	0	0	0	1	8	9	3	0	0	0
scba	7	4	2	2	0	1	3	0	0	1	0	21	38	26	**86**	22	49	24
hysa	23	30	13	21	13	14	28	2	0	8	7	25	28	8	**60**	17	34	16
erci6	23	25	3	6	5	12	35	13	24	22	7	8	21	12	**51**	11	29	13
amdu2	16	3	0	0	0	0	3	0	3	3	1	10	22	13	**43**	0	21	19
latr	9	9	0	8	12	4	25	0	24	38	16	22	29	10	**45**	3	16	10
peth4	0	0	0	0	0	0	0	0	0	0	0	0	6	14	**12**	6	6	2
opec	6	2	0	0	0	0	3	1	0	2	2	1	1	1	7	9	5	1
epca2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	36	**94**	59
isar	0	0	0	0	0	0	0	0	0	0	0	2	0	0	58	41	**82**	40

Appendix J. Continued

Species	a1,a2		a3,a4		a5,a6			a7,a8	a9		a10	a14		a11,a12		a13		a15
seflm	9	5	11	3	0	2	7	0	1	5	3	0	0	0	22	25	**31**	10
phar5	0	0	0	0	0	0	0	0	0	0	0	5	2	0	17	11	**18**	7
stli3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	17	**24**
opra	0	3	0	6	11	3	1	0	0	0	0	1	1	1	15	0	17	**21**

Appendix K. Two-way indicator table showing the species indicator values for the groups of Twinspan in the arroyo and wash dataset. The groups are abbreviated as follows: A=alliance and a=association. Boxes indicate groups in which species are indicators. See Appendix B for species codes and Figure 11 for group names. Bolded indicator values are significant with p<0.01.

veg type:	chlia/prfa		acgr/hysa		sado/	sado	acgr/	acgr/vipar		chlia/vipar		chlia/chpa		hysa			chlia/hysa	hysa		hysa			chlia/epca-hysa		epca		epca	
	A1		A1		A1,A2		A1,A4	A1		A3		A3,A5		A6			A3	A6		A6			A3		A7			
species	a3		a5		a1-2, a6		a4,a7	a9		a10		a11-12		a13			a13	a14		a14			a13		a15			
mimup	37	6	0	23	0	15	18	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
lyco2	32	**42**	18	7	0	0	0	0	0	0	0	0	0	0	5	1	0	2	0	1	1	0	0	0	0	0	0	0
yusc2	23	**41**	19	26	7	7	1	19	9	1	9	0	0	0	31	3	0	0	0	0	0	3	1	0	3	1	2	0
erpl3	0	**36**	33	6	0	0	0	0	0	0	0	0	0	4	4	4	0	0	0	0	0	13	4	0	4	0	0	0
dawr2	8	18	11	2	0	0	0	0	0	0	1	2	2	0	4	2	5	7	8	1	0	0	0	0	0	0	0	0
sado4	19	34	16	**76**	17	41	23	12	4	0	7	2	4	1	71	0	1	0	0	0	0	0	0	0	0	0	0	0
same1	22	31	14	**54**	15	27	13	1	1	0	1	0	0	1	41	5	0	3	0	3	3	0	0	0	3	5	6	0
mupo2	0	7	6	**39**	23	29	7	1	0	0	0	0	0	4	26	0	0	0	0	0	0	0	0	0	0	0	0	0
prfa	29	38	14	**39**	0	15	24	4	2	0	3	0	0	1	36	0	2	1	0	0	0	0	0	0	0	0	0	0
krer	0	24	23	**32**	7	14	8	3	1	0	1	0	0	3	27	0	0	1	0	1	1	0	0	0	0	0	0	0
adco	0	6	6	**29**	12	18	6	0	0	0	1	1	2	4	21	29	5	6	2	3	1	2	3	1	20	14	24	15
lyan	3	14	10	**29**	22	15	1	0	0	0	0	0	0	0	18	15	0	0	0	0	1	0	2	3	14	13	17	1
gaco5	0	0	0	17	**28**	20	1	1	4	3	2	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
orco4	0	0	0	7	14	5	0	0	0	0	0	0	0	0	5	0	12	3	0	0	0	0	0	0	0	0	0	0
yubr	0	0	0	51	43	**63**	22	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0
gumi	5	1	0	59	21	**62**	35	0	0	0	0	0	0	3	37	0	0	0	0	0	0	1	1	0	0	0	0	0
esvid	0	0	0	31	16	**38**	22	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0
mipu6	0	0	0	30	21	**36**	12	0	0	0	0	0	0	0	19	0	0	1	9	2	0	0	0	0	0	0	0	0
trmu	0	0	0	30	18	**35**	15	13	8	1	5	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0
acsp1	0	0	0	27	4	**31**	29	9	2	0	2	0	1	4	25	0	0	0	0	0	0	0	0	0	0	0	0	0
yuba	0	0	0	23	11	**27**	15	4	2	0	1	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0
mesp2	0	0	0	10	5	11	6	2	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	1	1	0
cora	0	0	0	22	1	27	**44**	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
fapa	0	0	0	14	0	17	**38**	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
oper	0	0	0	12	0	15	**26**	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
opph	0	0	0	11	0	13	**26**	1	13	12	7	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0
rhtr	14	2	0	15	0	12	22	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix K. Continued

species	a3		a5		a1-2, a6		a4,a7	a9		a10		a11-12		a13			a13	a14		a14			a13		a15			
cine	0	0	0	17	4	20	20	1	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0
caan7	0	0	0	11	1	13	15	2	1	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
erli6	0	0	0	7	0	7	15	10	3	0	3	1	1	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
brte	0	0	0	6	0	7	13	0	2	3	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
epvi	0	0	0	2	0	1	3	62	25	1	23	2	2	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
fecy	0	0	0	0	0	0	0	18	13	1	13	0	1	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0
oece2	0	0	0	16	9	17	9	3	39	35	24	0	0	0	38	0	0	0	0	0	0	2	0	0	0	0	0	0
pogr5	0	0	0	0	0	0	0	10	14	8	12	0	0	0	6	0	9	2	0	0	0	0	0	0	0	0	0	0
enfa	0	0	0	0	0	0	0	0	53	81	35	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
bejua	0	0	0	0	0	0	0	3	45	49	43	4	4	0	22	1	0	2	0	3	3	0	0	0	0	0	0	2
base	0	0	0	0	0	0	1	0	20	29	13	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
vipar	0	1	1	0	0	0	0	45	47	16	65	14	15	0	33	1	1	0	0	0	0	0	1	1	0	0	0	0
gusa2	0	0	0	0	0	0	0	40	54	24	60	7	7	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0
chpa	17	5	1	3	1	1	0	1	0	0	15	37	33	0	17	3	11	6	0	0	0	1	1	0	1	0	0	0
phhe4	16	1	0	7	2	3	2	0	0	0	11	30	31	0	19	1	10	3	0	0	0	0	0	0	0	0	0	1
phcr1	0	0	0	1	0	1	1	0	24	22	23	0	3	24	17	1	0	6	5	9	3	0	0	0	0	0	0	0
lori3	0	0	0	0	0	0	1	4	4	1	5	0	1	7	3	3	0	0	0	0	0	5	6	1	3	0	0	0
erpu8	2	6	3	28	11	18	8	6	25	17	40	10	17	5	67	0	0	0	0	0	0	0	0	0	0	0	0	0
acgr	14	26	13	40	7	18	13	13	17	7	27	4	7	2	66	11	7	4	1	0	0	5	3	1	6	2	3	0
pepap	0	0	0	31	14	33	18	20	37	16	33	1	4	6	64	0	0	0	0	0	0	0	0	0	0	0	0	0
amer	12	16	7	48	8	25	18	0	0	0	7	10	20	12	55	2	15	14	12	4	0	0	0	0	0	0	0	0
stpa4	1	2	1	21	9	14	6	7	13	6	28	11	19	6	52	12	13	15	5	5	2	3	3	1	4	0	1	4
epne	2	17	13	36	18	19	6	0	8	9	11	1	2	1	51	1	3	6	0	3	4	0	0	0	0	0	0	0
opapcc	0	3	3	29	11	22	11	7	15	8	16	0	2	17	51	2	6	10	8	6	1	0	0	0	0	0	0	0
spam2	2	2	1	21	9	13	6	9	10	4	26	10	17	8	50	5	26	9	2	0	0	2	1	0	1	0	1	1
enva	0	0	0	26	22	24	5	5	3	1	13	14	22	8	46	4	4	18	2	15	13	1	0	0	0	0	0	0
brma3	1	0	0	16	6	12	7	14	17	7	33	10	18	8	44	34	18	9	8	1	0	9	10	4	20	9	11	0
erin4	0	0	0	15	15	14	2	9	19	11	22	2	5	4	43	5	5	23	7	20	12	0	0	0	0	0	0	1
ecen	0	0	0	24	19	23	9	3	10	8	7	0	0	0	33	0	11	4	0	1	1	0	0	0	0	0	0	0
arpu9	0	0	0	22	18	25	6	29	17	2	10	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0
phca8	15	4	0	11	3	7	4	10	18	8	20	2	2	0	28	1	0	0	0	0	0	0	1	0	1	0	0	0
thmo	0	0	0	12	4	10	7	17	4	0	11	5	11	6	28	2	8	14	3	8	5	0	0	0	0	0	0	0
psco2g	0	0	0	11	18	9	0	19	4	0	8	6	6	0	21	0	4	1	0	0	0	0	0	0	0	0	0	0

Appendix K. Continued

species	a3		a5		a1-2, a6		a4,a7	a9		a10		a11-12		a13			a13	a14		a14			a13		a15			
opba2	0	0	0	13	7	14	5	0	5	4	4	0	0	3	18	2	0	3	5	4	1	0	0	0	1	1	1	2
chal11	0	0	0	14	15	11	2	0	0	0	3	15	13	0	17	1	4	1	0	0	0	1	1	0	0	0	0	0
alin	0	0	0	7	12	6	0	0	3	4	3	1	1	0	12	0	7	1	0	0	0	0	0	0	0	0	0	0
plri3	0	1	1	2	1	1	0	4	2	0	5	1	3	7	7	0	0	2	0	2	2	0	0	0	0	0	0	0
scba	0	1	1	2	1	1	0	0	0	0	5	8	15	8	6	81	22	36	8	14	8	12	21	12	44	11	20	13
isar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	6	6	0	2	2	23	32	14	69	17	35	24
hysa	8	16	8	17	6	7	1	0	3	2	9	3	8	11	27	64	14	35	10	18	9	7	15	8	30	7	14	7
erci6	1	7	5	19	6	10	5	8	8	3	17	7	11	4	35	52	14	21	8	9	4	6	14	8	29	8	15	8
latr	0	8	7	6	4	2	0	7	12	7	24	5	11	11	27	42	11	33	8	19	12	0	2	2	16	9	17	10
amdu2	0	0	0	2	3	1	0	1	1	0	4	7	7	0	6	40	1	20	0	19	22	2	3	2	19	12	24	19
phar5	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	19	0	1	8	2	0	3	8	5	17	3	9	3
crust	7	5	1	8	1	4	4	1	8	7	10	0	1	9	18	18	5	14	7	8	3	1	0	0	7	6	13	7
opra	0	18	16	2	0	0	0	0	0	0	0	0	0	0	1	18	0	1	0	1	1	13	3	0	16	4	11	16
peth4	0	0	0	0	0	0	0	0	0	0	1	5	4	0	0	9	6	2	0	0	0	0	7	10	6	0	0	4
chlia	17	3	0	6	0	3	6	1	15	18	25	7	6	0	27	13	34	8	0	0	0	1	8	8	5	0	0	0
brin	2	11	9	6	2	1	0	0	0	0	5	7	8	1	11	14	19	6	0	0	0	11	11	5	8	0	0	0
niob	0	0	0	2	3	1	0	1	4	5	7	2	2	0	8	1	19	5	0	0	0	1	0	0	0	0	0	0
mibi8	2	1	0	8	4	6	2	6	6	2	14	3	10	14	28	10	18	45	14	28	14	1	1	0	0	0	0	0
krgr	0	0	0	0	0	0	0	2	2	1	9	3	11	21	6	19	14	41	2	25	21	0	0	0	2	1	3	3
erfa2	0	0	0	8	3	6	4	14	3	0	14	12	20	8	27	12	25	38	14	16	7	0	1	1	1	0	0	2
sear8	0	0	0	0	0	0	0	3	1	0	11	9	26	22	7	19	12	37	15	21	7	4	2	0	3	0	1	12
cupa	0	0	0	0	0	0	0	0	0	0	2	4	7	5	1	6	5	12	8	5	1	1	1	1	1	0	0	0
moss	0	0	0	8	8	7	1	0	0	0	0	0	0	5	7	2	6	9	0	6	6	1	0	0	0	0	0	0
psarm	0	0	0	0	0	0	0	3	1	0	1	0	0	0	0	24	0	29	4	39	33	0	0	0	6	10	15	6
seflm	0	0	0	2	1	2	1	2	2	1	2	0	0	0	4	33	8	2	0	0	0	25	39	13	30	0	2	27
opec	0	0	0	2	2	1	0	0	1	1	0	0	0	0	2	9	6	5	0	1	2	4	9	6	5	0	0	0
epca2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	0	0	0	0	0	26	36	13	94	29	59	28
stli3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	1	17	37	29	0
lefrf	20	4	0	13	4	7	1	0	0	0	1	0	2	3	9	2	0	0	0	0	0	0	0	0	2	0	4	29