Vegetation of the Cabeza Prieta National Wildlife Refuge, Arizona

Vegetation Classification
for the
Endangered Sonoran Pronghorn

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December, 2003

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Final Phase -- Vegetation of the Cabeza Prieta National Wildlife Refuge

Items delivered, per the requirements of Cooperative Agreement CA 860197006-W02.

1) Digital maps of the vegetation of the Cabeza Prieta NWR. The digital maps exist both as Arc Info coverages and JPEG images. Samples of paper maps are provided. As agreed in coversation with Tim Tibbetts, Organ Pipe Cactus NM, a complete set of paper maps of the style and size desired will be delivered upon request.
2) Final report, with descriptions of methods and vegetation associations.
3) Digital maps of the routes traveled and the 340 sample locations (relevés).
4) Microsoft Access database of the samples. The labeled photographic slides, data sheets and field notes will be delivered with the paper maps.

Introduction

On March 11, 1967, the Sonoran pronghorn (*Antilocarpa americana sonoriensis)* was designated as Endangered. Within the United States, its habitat is almost entirely within public lands in Arizona administered by Organ Pipe Cactus National Monument (OPCNM), Cabeza Prieta National Wildlife Refuge (CPNWR), Barry M. Goldwater Air Force Range (BMG) and the Bureau of Land Management (BLM).

The Cabeza Prieta National Wildlife Refuge is the focus of this report, which is the second of two phases that describe and map the vegetation within pronghorn habitat. The first phase mapped the BLM lands near Ajo, Arizona.

Sonoran pronghorn migrate, seasonally and short-term, over considerable distances. Home ranges average 920 km^2, and can range up to 4067 km^2 (Hervert et al., 2000). Precisely what drives pronghorn movements is likely a matter of where there is food, which supplies both nutrition and moisture. The structure of the vegetation seems important, too: a tree can provide shade, but a thicket of trees may provide cover for coyotes and other predators.

The maps produced by this study can clarify the relationship between pronghorn movement, habitat use, and vegetation. For example, a pronghorn scat analysis (Hervert et al., 2000) found that white-bursage (*Ambrosia dumosa)* comprises 6.90% of pronghorn diet during critical dry summers. In contrast, triangle-leaf bursage *(Ambrosia deltoidea)* made up only 0.46%. Is white bursage actually preferred by pronghorn, and actively sought? Or is white bursage far more abundant than triangle-leaf bursage, and its high proportion in pronghorn scat merely a reflection of availability?

Another example is the Arizona Game and Fish (AZGF) study of the movement of radio-collared pronghorn (Hervert et al., 2000), which classified vegetation based on topographic features: bajadas, hill, drainage, mountain, sand dunes, flats and lava flows. In particular, "Areas classified as flats, sand dunes, or lava flow were predominantly creosote and white-bursage associations." (p.6)

About one-half of the 76,000 acres (31,000 hectares) mapped in the first phase of the study (the BLM lands) can be considered flats, with a slope of less than 3%. Of these "flats," about 58% hold white bursage with a cover of 1 to 4%. The other 42% of the flats have less than 1% white bursage, and should probably not be included in a statistical analysis as "predominantly creosote and white bursage." (Note, however, that the figure of 42% is based on the BLM lands alone, while the AZGF study encompassed all pronghorn habitat in the United States.)

The most detailed map available of pronghorn habitat is of Organ Pipe Cactus NM (Warren et al., 1981). Although the OPCNM map was not intended to specifically address the Sonoran Pronghorn, it served as a model for this study. The motivating idea was simple: gather enough data in the field to allow detailed photo interpretation of vegetation, to produce a map of Sonoran Pronghorn habitat outside the boundaries of OPCNM.

The study site

This phase of the study covered pronghorn habitat on the Cabeza Prieta NWR, approximately 500,000 acres east of the Tinajas Altas Mountains. Most of this land is

wilderness, with access limited to three dirt roads: Charlie Bell Road, Camino del Diablo, and the Christmas Pass Road.

Steep slopes are rarely used by pronghorn (Hervert et al., 2000; Marsh et al., 1999), so slopes exceeding 20% werre excluded from this vegetation classification. This was a logical break point from a vegetation perspective, too: the vegetation map of Organ Pipe Cactus NM (Warren et al., 1981) showed that associations usually changed at slopes of 20 to 25%.

The soils of the refuge have not been mapped, but reference is made to the soil map of the BLM lands adjacent to the east, created by the National Resources Conservation Service (NRCS); fieldwork ended in 1984, and the study was published over a decade later (Johnson, 1997). The report is available in both print and digital form; the latter can be obtained as a "coverage" that can be imported into a GIS (http://www.ftw.nrcs.usda.gov/ssur_data.html). This report includes a nice cross-section (Figure 16) showing the soils of the Valley of the Ajo, the eastern side of the study site. In general, soils are finest in the valley centers, along flood plains, and the soils are increasingly course as you move upslope, across alluvial fans, fan terraces, and ultimately up steep mountain slopes.

The town of Ajo, at 1750 feet (533 meters), is at the edge of the study area, and has weather records dating from 1914 that are summarized by the Western Regional Climate Center (The center is administered and funded by NOAA; data is at http://www.wrcc.dri.edu/). Mean rainfall is 8.5 inches annually, which is nearly evenly split between the cool and the hot seasons: 4.12 inches from October to March, and 4.38 from April to September. The average maximum temperature during the hottest month, July, is 103°F. The average minimum during the coldest month, January, is 41.5° F.

Methods

The intent was to duplicate the methods and vegetation associations used by Warren et al. (1981) in mapping Organ Pipe Cactus NM, using field surveys and samples ("relevés") to interpret aerial photos. In the end, the field methods were changed to adhere more closely to the standards of the National Vegetation Classification System (NVCS), and the method of producing the maps was not with clear plastic overlays, like Warren et al., but with a computer and a geographic information system (GIS).

The changes in the field methods were influenced by the Vegetation Classification workshops at the 1999 and 2002 meetings of the Ecological Society of America (ESA). Here I discovered little sympathy for the method of prominence ranking used by Warren et al. (1981), where a species' abundance is ranked on a scale of 1 to 5 (details below).

The ESA meeting showed the importance, and difficulty, of moving towards a National Vegetation Classification System, the "NVCS". (Grossman et al., 1998; see also http://www.esa.org/vegweb/#phase1). The importance is in developing a common protocol for measuring and naming plant associations. The difficulty is in applying similar methods for associations ranging from forests to desert. The methodology is tilted towards forests, where most classification takes place. For example, as of March, 2003, there are 254 plant associations described by the NCVS within Arizona. Only 4 of these are in areas of "sparse" vegetation, where ground cover is less than 25%. In

contrast, in this study at least 10 of the 16 associations decribed have less than 25% cover. These 10 associations comprise over 80% of the study site.

In any case, this study needed a field methodology that extended the methodology of Warren et al. (1981) to fit with the NVCS.

An example of how the samples were taken

Warren et al. (1981) used "relevés," a method that is neatly summarized in the *Manual of California Vegetation* (Sawyer and Keeler-Wolf, 1995).

"The relevé method of sampling vegetation was developed in Europe and was largely standardized by the Swiss ecologist Josias Braun-Blanquet. (…) The relevé is particularly useful when observers are trying to quickly classify the range of diversity of plant cover over large units of land. In general, it is faster than the point intercept technique. One would use this method when developing a classification that could be used to map of a large area of vegetation, for example. This method may also be more useful than the line intercept method when one is trying to validate the accuracy of mapping efforts.

"The relevé is generally considered a "semi quantitative" method. It relies on ocular estimates of plant cover rather than on counts of the "hits" of a particular species along a transect line or on precise measurements of cover/biomass by planimetric or weighing techniques."

In Warren et al. (1981) the relevé method was used to estimate the "prominence" of species (see below). In this study, the method was as follows:

Let's say I find myself in a locale that appeared representative of what Warren et al. (1981) called the creosote/white bursage association. With clipboard in hand, I walk and take note of every perennial species (and annuals, if unusually abundant) until I stop finding new species. Generally, this happens within 100 to 500 meters (330-1640 feet), depending on the association. An average figure would be 200 meters (660 feet). The width of the sample depends on the plant and the association. A linear strand of vegetation in an arroyo is restricted to that arroyo, which may be as narrow as 5 to 10 meters (16-33 feet), including vegetation. Outside of arroyos, the average width of the sample is around 40 meters (131 feet), which is to say that most of the perennial species could be spotted from 20 meters (66 feet) off the line of travel, at least in open habitat. Some plants, like a saguaro cactus, can be noted from a far greater distance than a clump of fluff grass.

An average sample site of 200m x 40m is a total area of 8000m^2 (2 acres) surveyed for ranking species prominence. Coverage was assessed on a smaller scale within the sample (see below).

Ranking species prominence

After the species are listed, they are ranked from 1 to 5 in order of relative prominence. A clearly *dominant* species is a 5, while two or more *co-dominants* are 4's. If a "5" is present, then there are no "4's" and vice-versa. The remaining species are

common (3), *uncommon* (2), or *rare* (1). Rare is when there are only one or two individuals in the sample.

The dividing line between common and uncommon is more difficult to pin down by numbers alone. One way to quantify this otherwise arbitrary judgment is to imagine if all the individuals of a particular species in a 100 by 40 meter (one acre) sample were lumped together. If their summed coverage exceeded a 4-meter square ($16m^2$/172 ft^2) they would be ranked as common, despite having well under 1% cover. In fact, they would have about 0.4% cover, which I offer here as a cutoff between *common* and *uncommon.*)

For example, the average bursage is around 0.4 m (16 inches) in diameter, so 100 bursage would fit into the 4-meter square area. Hence, estimating around 100 or more bursage while walking 100 meters would result in calling them "common,"

Trees and big cactus (e.g., saguaro/organ pipe) are assessed differently, because they can branch out far beyond their base. For example, only 10 to 15 individuals (depending on their size and branching) in 100 meters would rank them as common. This assumes that the coverage of a single big saguaro is roughly similar to that of ten bursage – about 4 m^2. This wasn't checked, just assumed, because the attribution of dominance/co-dominance is more important than the distinction between common and uncommon.

Estimating coverage

Because the Warren et al. (1981) study emphasized "prominence," it did not include cover estimates of individual species. Neither did this study, at least formally, for the first several months. During this time, estimates of cover were strictly visual ("Looks like 15% creosote"). I also spent two days at the study site with Peter Warren, estimating coverage.

After attending the vegetation classification workshops at the Ecological Society of America, it was apparent that a repeatable estimate of cover would be needed to fit this study into the larger scheme of the National Vegetation Classification Standard (NVCS). Precisely what the method should be was left open, because what works for a deciduous forest may not work for the desert. The "rapid survey method" of McAuliffe (1990) is explicitly for desert plant communities, yet a trial showed that it was not rapid enough – it still took an hour, with a rangefinder.

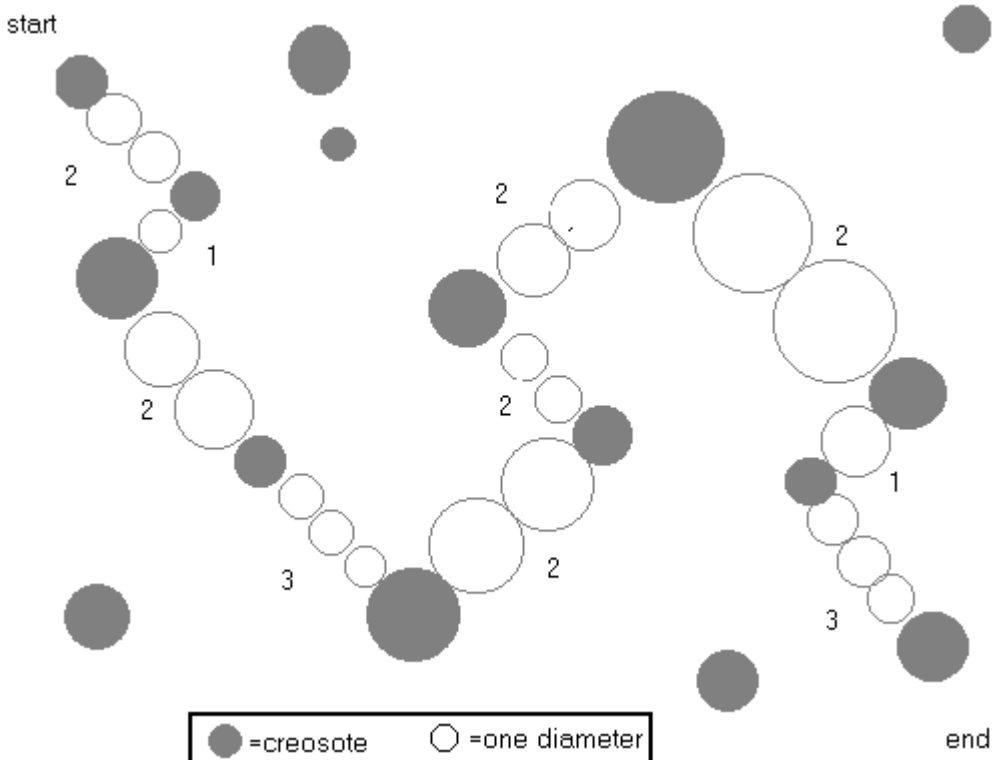
This left "visual estimates." The objective was to find a method that allowed for greater precision rather than accuracy – a method that would be repeatable. The result was a method that uses two metrics: the diameter of an individual plant, and the distance to the next individual of the same species. The unit of measurement is not meters or feet, but instead the number of diameters of the last individual measured.

For example, if a creosote is a meter wide, and it is 3 meters until the next creosote bush, the distance between is 3 creosotes. If the second creosote is 1.5 meters wide, and it is 3 meters to the third creosote, then the distance between is 2 creosotes. The "next" creosote is always the next closest creosote, excluding the last creosote measured (can't go backwards).

In practice, I walk between individuals of the target species, counting off the diameters between each individual creosote, estimating the distance to the nearest whole

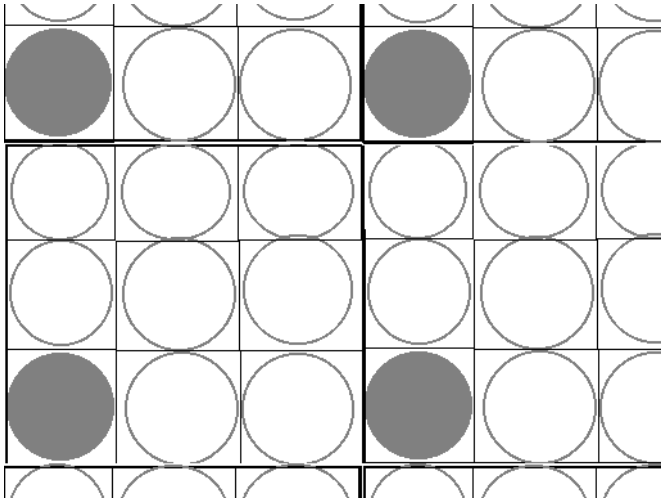
diameter. I sum the diameters in my head as I walk along (2 diameters, 3, 5, 8, 10...) until I've recorded 10 between-individual distances. The summed total (for example, 20 diameters) is then divided by 10 to get the mean number of diameters between individuals. In this case the mean number is 2 diameters, meaning that, on average, there was one creosote, then a space equivilant to two creosote, then another creosote, and so forth.

In the example below, the numbers indicate the distance in diamaters between creosote, if you start at the top left. The mean distance in this example is two diameters.

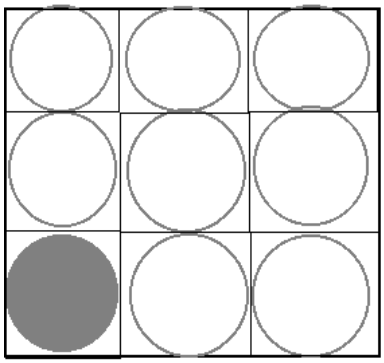


(Note: this illustration for educational purposes only – it was drawn without the benefit of actual measurements)

Working out the geometry of this configuration (which can be done with pool balls at the XY Saloon in Why, Arizona) shows the relationship between the mean number of diameters and the percent cover of the target species. First make the assumption that the mean distance between creosote is two diameters. If so, the creosote within the sample could be uprooted and rearranged in the same sample area, with each creosote (shaded) two diameters from its neighbor.



The repeating element in the grid is shown below. If the creosote happened to be box-shaped, it would cover 1/9 or 11% of the area. But because the creosote is round, or at least as round as a creosote gets, the figure is about 9% cover.



If the individuals were sepereated by a mean distance of 3 diameters, the percent cover is 5%. If only a single diameter, the figure is 20% (Other figures include: 8 diameters = 1% cover; 1.2 diameters = 15%; and 0.75 diameters = 25%).

The estimate of individual's diameter was the visual average of the largest and smallest diameter. During dry times in the desert it is impossible to tell what part of a plant is alive or dead, so every stick counted. The result is the same as if you had thrown a sheet over the plant, and imagined a leafy globe beneath. This results in a higher estimate of cover than you would get using an aerial photograph alone, where only the denser foliage appears.

The "diameter" method was adopted as the study was in progress. To compare the cover estimates to those I'd made earlier in the study (using a simple visual estimate),

I revisited several sites. The diameter method gave lower cover estimates than I'd made earlier. *The median coverage figures for each association (see summary statistics, below) are, unfortunately, a composite of both methods – visual and diameter – and are likely higher than the diameter method alone would give.* (For the second phase of the study – Cabeza Prieta NWR – only the diameter method was used.)

Cover estimates were made only for common species with over 1% cover. These were converted into cover classes, because the NVCS requires such classes. The minimum standards for coverage classes at the 1999 ESA workshops were the Braun-Blanquet scale, which has a set of class boundaries at 1%, 5%, 25%, 50%, and 75% -- woefully inadequate for describing desert vegetation. Three years later, at the 2002 workshop, the 5-25 % class had been subdivided to include cover classes of 1-5%, 6-15% and 16-25%. By this time, however, I'd already developed a set of cover classes that added yet another division on the low end, resulting in a scale (Table 1) that is, luckily, almost congruent with the NVCS system.

When species were clumped – as with leguminous trees in watercourses too small to be mapped – the method was to estimate the cover in the arroyo, then to estimate the amount of the sample site that is arroyos by walking perpendicular to the watercourses and counting the number of steps between.

When estimating cover within arroyos that were mapped separately, I simply estimated the % of the bank inhabited by each species.

As shown in the sample data sheet in Figures 1 and 2, other data recorded included a description of the soil surface, topographic position, landform, geology, aspect and slope gradient (estimated with a simple homemade inclinometer made of a protractor, string, and small weight). Data sheets were labeled with the first letters of the name of the 7.5 quad sheet, sequentially numbered (e.g., the first sample from the Chico Shunie quad was CS-1). The location was determined with a GPS and recorded in UTM coordinates in NAD 1927 so I could find the correct elevation (and myself) on the map. A photograph was taken of each sample site, and the compass direction of the photo recorded. The photos were slide transparencies. Also recorded was the mean height of the most common species, estimated to the nearest 10cm, with the exception of trees, whose height was estimated to the nearest 0.5 m.

The data were entered into an "Access" database (Microsoft Office 2000), and later summarized in the descriptions of the associations.

As the study progressed, it was apparent that more data were needed to distinguish between, say, creosote/white bursage and a creosote/triangle leaf bursage associations. The best way to gather data quickly was not to take a full sample that was meant to statistically describe an association, but instead hike across a valley and take quick samples, stopping when the vegetation changed, noting my position with the GPS, then recording directly on the quad sheet the prominence and cover of the most common species at that location. These data were critical for drawing the boundaries of the various associations.

Cover Class	% cover
0	unknown
1	<1%
2	1-4%
3	5-9%
4	10-14%
5	15-25%
6	26-40%
7	41-60%
8	61-80%
9	81-100%

Table 1. Cover class scale used in this study

VEGETATION RECORD

Investigator: Malusa	Date: redo of 7 May 99 (12 June 00)			Rec.No.: CM-4	Relevé No.
Land Ownership: BLM	Administrative Unit	Administrative Subunit		State	County
Relevé Name	Relevé Location: 1/2 km south of Charlie Bell Rd, at Cabeza Boundary.				
Slope Percent: Small hills. 5-25%	Aspect: N NE E SE S SW W NW L	Elevation (M/Ft.): 1640 ft.		Area (Ha/Ac.)	
Georef Coordinates (Lat./Long. or UTM): 32 86 200 N 3 18 400 E		Zone (for UTM)	Airphoto Id. & No.		
Context Photo: 80°	Content Photo	Other Photo	Other Photo	Remote Sensing Ref. DBF Nos.	TM	Spot or other
Soil Series: much old mining disturbance		Soil Formation: Stony - varies from micaceous schists to an intrusive igneous			Soil Color	
Boulder(>256mm)	Cobble (64-255)	Gravel (3-256)	Sand (2-0.16)	Silt	Clay	Soil Texture

Circle: Rockpile Bajada Valley bottom fill Drainage Channel (Side slope) Lower slope Mid slope Upper slope Ridge Floodplain Interfluve Terrace Mesa Cliff Talus/scree Cinder

Circle: Alluvium Conglomerate Sandstone Siltstone Shale Limestone Serpentine Marble Schist Gneiss (Intrusive igneous) Extrusive igneous

Adjacent to: Paved road Dirt road Drainage Grazing Buildings Urban Agriculture Cliff Fenceline Wasteland Wildland

Code	Name	Prominence	Spacing E R C	Coll. #
Cemi	4			
Lath	2			
Ande	4			
Olle	2 - last small, and restricted, usually to drainages			
Enfa	3			
Mide	2 Also Albizia.			
Krer	2			
Cagi	2			
Fosp	3			
Feem	1			
Opbi	2 - a couple patches			
Opac	2			
Opfu	2 -			
Krgr	2			

Prominence codes: 5=Dominant; 4=Codominant; 3=Associate; 2=Uncommon; 1=Rare

Figure 1 – Sample Data Sheet

Investigator	Date			Rec. No.	Relevé No.

Code	Name	Prominence	Spacing E R C	Coll. #
Chri	2 all dead			
Ecen	1			
Caer	2 locally common along some drainages			
Lybe	2			
Eriogonum	2 trumpet-like			
Erpo	2 fl-yl grass – locally common			

Prominence codes: 5=Dominant; 4=Codominant; 3=Associate; 2=Uncommon; 1=Rare

Layer	Height Code Mn	Mx	Av	Cover Code	Notes: Dead
Tree Ceni		~2.5m		5-10%	Little grass/forb cover
Tree Ande		0.3m		5-10%	
Shrub Olde		2.0 m		1%	
Forbs Erfa		0.5m		2-5%	– mostly leafless – highly variable cover, sometimes absent
Graminoids Lehr		1.0m		1-2%	
Moss					
Litter					
Bare					

Height Code: 6= >21m; 5= 9m ≤ 21; 4= 3 ≤ 9m; 3= 1 ≤ 3m; 2= 0.3 ≤ 1m; 1= 0 ≤ 0.3m

Cover Code: 9= 90 > 100%; 8= 80 ≤ 90%; 7= 70 ≤ 80%; 6= 50 ≤ 70%; 5= 30 ≤ 50%; 4= 15 ≤ 30%; 3= 5 ≤ 15%; 2= 1 ≤ 5%; 1= < 1%.

Figure 2 – Back Side of Sample Data Sheet

Describing plant associations

Various systems of classifications have emerged over the years, with the Brown, Lowe and Pase (1979) system favored in the southwest because of its local roots. But on the scale of the entire country, and beyond, it appears the winner will likely be the National Vegetation Classification Standard (NVCS) (Grossman et al. (1998), available at http://www.conserveonline.org/2001/03/p/en/vol1.pdf.)

The NVCS and Brown, Lowe and Pase (BLP) have a similar hierarchical structure in which they combine physiognomy and broad climatic patterns in the upper levels of the hierarchy, and lower levels based on species or suites of species. There are also several differences. First is the irksome tendency to give different names to what seems to be the same thing: the BLP "*association*" is the level below "*series*," while the equivalent NVCS "*community element*" is the level below "*alliance*." NatureServe (www.natureserve.org) is the most visible repository of NVCS data. It uses the International Classification of Ecological Communities, which seems to be the same as the NVCS, albeit with nomenclature changes such as favoring "*association*" over "*community element*." Further, Nature Serve claims the backing of the Federal Geographic Data Committee, the protocol to be used by *all* U.S. federal agencies. The National Biological Information Infrastructure (NBII), part of the United States Geological Survey, claims allegiance to the NVCS, but also uses "association" instead of "community element," so it appears that *association* has won.

Second, and more importantly, the BLP is based on the dominant overstory of *climax* vegetation, while the NVCS is based on the dominant overstory of *current* vegetation. Distinguishing climax vegetation from current vegetation makes little difference in this study, in which plant communities are relatively undisturbed and hence current and climax vegetation are the same. (Exceptions would include areas that are heavily grazed, or occasionally flooded after uncommon storms, such as a November hurricane).

Finally, at a high level within the hierarchy, there are irrevocable differences in describing watercourse (arroyo) and mesquite bosque habitats: BLP puts them under wetlands/riparian systems, while the NVCS says wetlands/riparian areas must hold hydrophytes, and classifies arroyos as "Intermittently flooded extremely xeromorphic deciduous subdesert shrubland" and bosques as "mesquite woodland."

All the associations mapped in this study (including previously undescribed associations) are "cross-walked" between three systems of classification: Warren et al., the BLP, and the NVCS. Warren et al.(1981) is supposed to be equivalent to the BLP system. It often isn't, at least in terms of the particular number assigned, and these differences are noted in the summary descriptions below.

Mapping plant associations, steep slopes, and denuded lands

The vegetation maps were derived from high-elevation aerial near-infrared photos taken in June of 1996. Unfortunately, because the summer rains begin in July,

virtually every plant is shut down in June and does not show up as red on the photos. Fortunately, the photos have a resolution of about one meter (3.3 feet), and exist in uncorrected print and in digital format ("DOQQ"). In print form they are at a scale of approximately 1:40,000. The digital format is rectified to correct for the distortion of distance inherent in an aerial photograph from a single point.

A geographic information system (GIS) marketed as ArcGIS included the ArcMap program, which was used to draw the maps "over" the digital photos. This provides two advantages: the maps can be printed/viewed at any scale, and other digital maps, such as topography, soil types or the seasonal movements of pronghorn, can be superimposed over the vegetation maps.

Slopes steeper than 20% were not part of the study. A Digital Elevation Model (DEM) was processed to find all "cells" with >20% slope. The cell size is 30m square. This method also found flat mesas atop mountains that, despite shallow slopes, were not mapped, because it's presumed the pronghorn wouldn't climb the mountain to get there. The remaining steep slopes were a mapping unit.

Areas that were denuded by the action of cows or people (primarily RV campers, mines, ATV playgrounds, and cattle tanks) were mapped directly from the photos.

The plant associations were drawn on the computer screen, usually at a scale between 1:3,000 and 1:5,000. The minimum mapping unit was generally one hectare (100m x 100m), or about 0.4 acres. (Some features, like cattle tanks, are mapped even though they're less than 50 meters in diameter (<0.25 hectares).) The resolution of the print photos were better than the DOQQs, so I kept the prints at hand, checking them with a large magnifier equipped with a circular fluorescent bulb.

I could not have identified the particular pattern of vegetation on the DOQQ without fieldwork. The 197 samples that allowed a statistical description of the associations were essential to drawing the maps. Equally important were the "quick samples," mentioned above, that were merely recording the prominence and cover of the most common species, while on a series of walks that ended up covering about 400 kilometers (228 miles). An additional 200 kilometers were on roads, driving slowly and taking data when it seemed relevant, i.e., whenever the vegetation changed. The routes were recorded with ArcGIS and are included with the rest of the field area.

Almost all of the mapping units were "polygons," meaning that they were enclosed by a perimeter line. But if the floodplain and watercourse habitat was less than ten meters (33 feet) across, it was too narrow (at this scale) to completely enclose with a polygon, so they were drawn as linear features. The criteria used in choosing where to draw the lines are discussed in the synopsis of each plant association, under the heading "Photo Identification."

Field data were recorded in NAD 1927 datum, and entered in the database in NAD 1927; the computer mapping, however, was in NAD 1983, which is the datum of the DOQQ's and the digital equivalents of a topo sheet ("DRG"). This is not a problem for the GIS program; when so informed, it simply transforms the data and displays it in the correct locale. The final product – the vegetation map – is also in NAD 1983.

The digital version of the maps holds an information file with further data on the methods.

Results

Fieldwork on the Cabeza Prieta NWR was largely completed by 2002. Within the refuge and the Mohawk Mountains region of the adjacent Goldwater Range to the north (also pronghorn habitat) I took 259 samples of vegetation; an additional 81 came from a four-mile wide slice of the adjacent BLM lands, and are included in the summaries of the associations below, to bolster the statistical descriptions with more data – a total of 340 samples. 160 species were recorded. The only perennials that were not recorded were members of the cactus genus *Mammillaria,* which were deemed not worth the time to find and identify in this study.

Two factors affecting plant associations within the study site: soils and frosts

The soils are pretty good predictors of plant associations. The fine or very fine sandy loams are dominated by creosote, mesquite, and bursage associations. Alluvial outwash from the mountains creates bajadas (alluvial fans) with gravelly loams favored by paloverde and ironwood tree associations. Limy deposits on mountain slopes that have escaped erosion form caliche terraces that support dwarf communities of leguminous trees, or no trees at all.

Frost and elevation also affect plant associations, but in a curious way: the most frequent frosts are in the lowest places, on the valley floors.

For example, Ajo, situated upslope at 1750 feet (533 meters), has an average of 5.5 days each year with temperatures below freezing. The town of Tacna, about 50 miles (80 km) northwest of the study site, sits at only 310 feet (94 meters) in the Gila River Valley. Tacna is hotter than Ajo, winter and summer, typically by 3 to 5 degrees. (Tacna's January maximum averages 68.6ºF vs. 64.0ºF for Ajo) Yet, close to the valley floor, Tacna is much colder at night, with 33.1 days each year of below freezing temperatures. (http://www.wrcc.dri.edu/).

There is no weather station in the largest basin in the study area, the Valley of the Ajo, but personal experience and the distribution of frost-sensitive plants shows that such freezes are common at the lowest elevations in the study site. The frost-sensitive species are well upslope, and the most frost sensitive – like the elephant tree (*Bursera microphylla)* – are only on mountain slopes. Other species, like the ironwood (*Olneya tesota)* and jumping bean (*Sebastiana biloculare)* are often frost-damaged at lower elevations, and unscathed upslope.

Species and Associations

There were 20 plant associations described and mapped. In addition, there were 3 non-plant mapping units: (1) lands steeper than 20% slope; (2) lands significantly altered by people or livestock (usually barren, or mine tailings); and (3) mountaintops and mesas isolated by slopes >20%, and not mapped. Figure 3 shows the total acreage of all 23 mapping units.

(NOTE: the association acreages in Figure 3 for the *creosote/mesquite floodplain* and *watercourse with bed less than 5m wide* are the sum of the polygon acreage and 'linear acreage." Because the computer doesn't figure out the area of lines, only the length, the "linear acreage" was based on the following: (a) 79.6 km of linear *creosote/mesquite floodplain;* (b) 162.6 km of linear *watercourse with bed less than 5m*

wide; and (c) in both associations, that the average width of the strip of vegetation is 7.5 meters (25 feet). This adds about 300 acres (122 hectares) to the small watercourses, a significant addition to the 742 acres (301 hectares) mapped as polygons, and about 150 acres (61 hectares) to the creosote/mesquite floodplain, an insignificant addition to the 7483 acres (3031 hectares) mapped as polygons.)

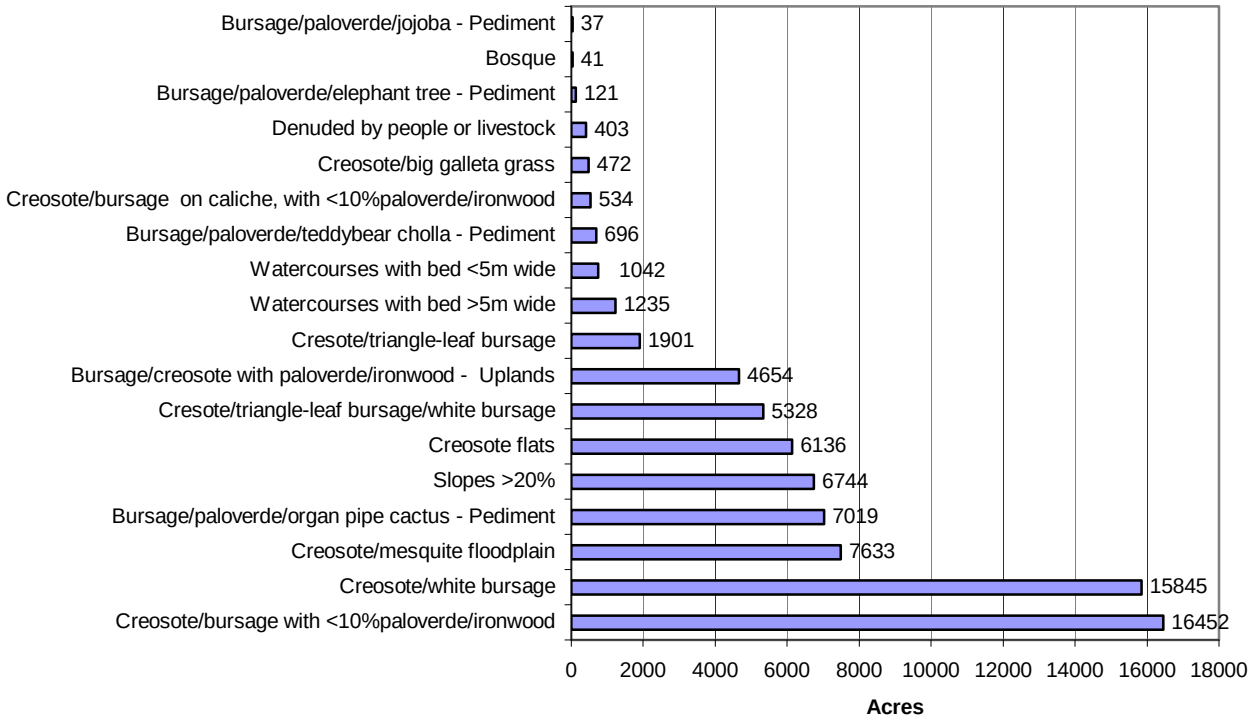


Figure 3 -- Acreage of Mapping Units on Cabeza Prieta NWR (including linear habitat)
(total area = 75, 857 acres = 30,722 hectares)

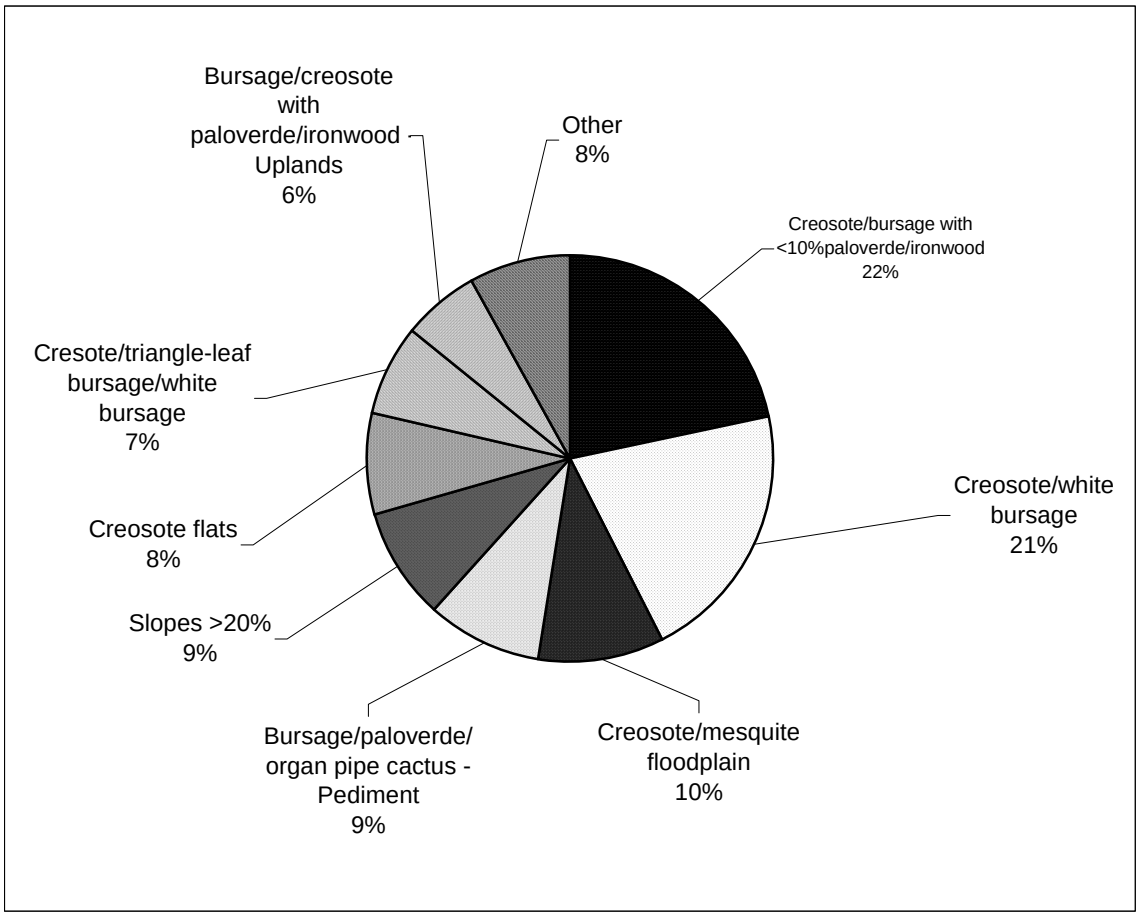


Figure 4 – Proportion of the study lands occupied by (a) the seven most common plant associations, and (b) slopes steeper than 20%.

About 9% of the CPNWR lands were too steep to be mapped by this study; the remaining 91% are dominated by seven plant associations (Figure 4). In five of these seven associations, covering 68% of the study area, creosote is either the dominant or co-dominant plant. Triangle-leaf bursage or paloverde is the dominant or co-dominant plant in the other two associations, which cover about 15% of the study area. The rest of the study area – about 8% - is shared by nine associations. Three are characterized by either a bosque or watercourse, three characterized by creosote, and three characterized triangle-leaf bursage or paloverde.

Naming Associations

If possible, associations were named with pre-existing names, typically from Warren et al. (1981). Otherwise, they were named with the dominant plant first, and others listed in order of decreasing abundance. If the species in a list are separated by a "/" symbol, they were judged to be in the same height class ("stratum"); if separated by a hyphen, they were in separate strata. (The relevant NVCS strata are 25cm-50cm, 50cm-1m, 1-2m, 2-5m, and 5-10m).

The NVCS is, however, inconsistent with its rules; for instance, they list a *Larrea tridentata-Ambrosia dumosa* association, which should, based on height, be *Larrea tridentata/Ambrosia dumosa*. If an association is named by more than one species, the NVCS suggests that the order should reflect the relative dominance (as I did here), or that the order should reflect the stratum, with the highest listed first. It does not suggest what to do if the two criteria – dominance and stratum – are in conflict.

Remarkably, *Larrea tridentata* (creosote bush) was in 195 of 197 sample sites – everywhere but two large and very shady arroyos. In all, 8 of the 16 plant associations were characterised by the ubiquitous creosote bush – it was dominant or co-dominant. These associations were judged to be part of Brown, Lowe and Pase's "Lower Colorado" series (which is sometimes called a "subdivision"), and hence all are classified under 154.11x. One of the associations, the Creosote/Bursage-Ratany/Paloverde-Ironwood association (154.117), was encountered in two forms: "normal" and "stunted," with the latter found only on caliche substrate. These two forms were numbered as "sub-associations" 154.1170 and 154.1172. (the missing figure, 154.1171, describes yet another variant, from the Cabeza Prieta NWR).

Warren et al. (1981) describe and map a *Larrea tridentata-Ambrosia dumosa* association, which, in their scheme, includes both *Ambrosia dumosa* and *A. deltoidea,* sub-dominant to *Larrea tridentata*. In light of the scat analysis of Hervert et al. (2000), which suggests *A. deltoidea* is unpalatable to pronghorn, this association was divided into three associations for this study: *Larrea tridentata/Ambrosia dumosa (154.111), Larrea tridentata/Ambrosia deltoidea (154.112),* and *Larrea tridentata/Ambrosia deltoidea-A. dumosa (154.113).*

Two new plant associations were described, both which apparently lie beyond the bounds of Organ Pipe. First is a *Larrea tridentata/Pleuraphis (=Hilaria) rigida* association (154.116), usually on sandy swales, where the *Pleuraphis* (big galleta grass) is at least common, and sometimes co-dominant or dominant. The second is an *Ambrosia/Parkinsonia/Opuntia bigelovii* association (154.124). It's found on mountain

pediments, in habitat very similar to *Ambrosia/Parkinsonia/Stenocereus* (154.122), except beyond of the range of *Stenocereus* (organ pipe), which is limited by low precipitation. In this instance I searched for a species characteristic of the "old" organ pipe association. I considered *Opuntia fulgida*, but other data showed that it was not restricted to the mountain pediment. Likewise, *O. acanthocarpa* and *Carnegiea gigantea* are much more broadly distributed. *Jatropha cuneata* seemed a good choice, because it is frost-sensitive like the organ pipe – but it was present in only 6 of the 36 organ pipe sites. Teddy bear cholla (*Opuntia bigelovii*) seemed the best choice: it was in 2/3 of the organ pipe sites, nearly absent from other associations, which indicated a strong preference for the same sort of habitat favored by organ pipe, namely rocky uplands. Ideally, the species would allow mapping with photographs alone, but in this case there was no such species. Happily, the teddy bear cholla still works as an indicator species because it is, like the organ pipe, highly visible and thus mappable with a pair of binoculars.

Association Descriptions

Association: *Larrea tridentata* monotype (Creosote bush)

Classification: 154.110

Warren et al. classification: 154.1114 - *Larrea tridentata* with annuals

Brown, Lowe and Pase classification: 154.111 - *Larrea divaricata* association

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: There is a *Larrea tridentata* monotype shrubland currently in the database; the association in this study is a *Larrea tridentata* monotype sparse shrubland.

Description: Stands of pure or almost pure creosote bush. During wet winters, annuals such as *Amsinkia* and *Lepidium* can be abundant, usually sheltering beneath the creosote. Scattered *Pleuraphis rigida* and *Prosopis glandulosa and velutina* are rare but present in 9 of 20 sites. Also rare, and present in 5 or less sites, were *Ambrosia dumosa, A. deltoidea, Ferrocactus wislizenii,* and *Carnegiea gigantea*. Compared to the BLM lands to the east (Malusa, 2003), the creosote here are slightly smaller (1.2 m vs. 1.3 m) and with sparser cover.

Location: At elevations of 475 - 1380 feet (150 – 425 meters), on slopes of 0 to 3%, on fan terraces or flood plains. Such places are typically in or near the center of the valleys; however, flats can also be found close to the foot of steep mountains and bajadas.

The soils of Cabeza Prieta are not mapped, but soils associated with creosote flats on adjacent BLM lands to the east are either the Dateland-Cuerda complex, characterized by upper strata of fine or very fine sandy loams, or stratified loams; and the Denure-Rillito-Why complex, which generally lies a bit further upslope, and includes soils with gravelly sandy loams and sandy loams, sometimes with pebbles over much of the surface (Johnson, 1997). The association usually grades into creosote/bursage associations, or, where waters collect, into creosote/mesquite floodplain with poorly defined channels. Along large channels (arroyos with beds greater than 5 meters wide), creosote flats are sometimes found on the inside of a broad bend.

Field Identification: An observer can stand amid the creosote and not see a bursage. There are often a few bursage tucked in runnels, but seeing them requires some searching. However, if runnels are common, and so are the bursage within them – say, a dozen bursage every twenty meters – the area was then considered one of the creosote-bursage associations.

On the BLM lands adjacent in the east, this association did not include any mesquite, but here the rule was stretched to allow a tree or two within lands mapped as creosote flats. Similarly, if there were scattered hummocks of big

galleta -- *Pleuraphis rigida* -- it was mapped as a cresote flat so long as the big galleta had less than 1% cover, and either species of *Ambrosia* was absent or rare.

Photo Identification: Stands of pure creosote were recognized by their habit of each bush being regularly dispersed, with no other vegetation between. This makes a pattern of distinct dots on the photo.

Association: *Larrea tridentata* monotype (Creosote*)*

Classification: 154.110

Number of sample sites: 20

taxon	sites	median prominence(range)	median cover(range)	mean height(in meters)
Larrea tridentata	20	5 (5)	5-14% (1-25%)	1.4
Pleuraphis rigida	9	0 (0-3)	0 (0 to <1%)	0.7
Prosopis spp.	9	0 (0-2)	0 (0 to <1%)	
Ambrosia dumosa	5	0 (0-1)	0 (0 to <1%)	
Ambrosia deltoidea	5	0 (0-1)	0 (0 to <1%)	
Ferrocactus wislizeni	4	0 (0-1)	0 (0 to <1%)	
Carnegiea gigantea	3	0 (0-1)	0 (0 to <1%)	

Association: *Larrea tridentata/Ambrosia dumosa* (Creosote/White Bursage)

Classification: 154.111

Warren et al. classification: part of 154.1111, which, in their scheme, include either/both *Ambrosia dumosa* and *A. deltoidea,* sub-dominant to *Larrea tridentata*.

Brown, Lowe and Pase classification: 154.112 – *Larrea divaricata/Ambrosia dumosa* association.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: There are two currently listed. The first is a *Larrea tridentata - Ambrosia dumosa* shrubland; however, this is reported only from the Mohave Desert, in Nevada and California. The second is the *Ambrosia dumosa-Larrea tridentata* var. *tridentata* Dwarf-shrubland, listed from Arizona; however, *A. dumosa* is listed first, implying it is generally dominant or co-dominant over creosote, which is not the case in this study. Also, "dwarf" means less than 0.5 m tall, while the mean height of the *Larrea* in the association described here is 1.4 m.

The association in this study is best described as a *Larrea tridentata/Ambrosia dumosa* sparse shrubland.

Description: Creosote is dominant or, occasionally, co-dominant with *Ambrosia dumosa. A. dumosa* is common, but its median cover is only 1 to 4%, compared with 5 to 9% for *Larrea. Pleuraphis rigida* is at 17 of 20 sites, and typically uncommon, with a median cover of <1%. *Ambrosia deltoidea* is present at 9 of 20 sites, and either rare or uncommon. Species that are occasionally common (i.e., ranked a "3"), but usually absent are *Ferrocactus wislizeni* (9 of 20 sites), *Prosopis spp.* (8 sites), *Krameria grayii* (7 sites), *Carnegiea gigantea* (6 sites), *Opuntia kunzei* (2 sites), and *Opuntia ramosissima* (2 sites). Other species include *Erioneuron pulchellum* (fluff grass, 4 of 20) and *Castela emoryi* (crucifixion thorn, 2 sites).

Compared to the BLM lands to the east (Malusa, 2003), the creosote is smaller on the refuge (1.2m vs. 1.4m) and sparser (cover is 5-9% vs. 15-25%), but still dominant or co-dominant with white bursage.

Location: At elevations of 375 - 1680 (115-520 meters), typically on shallow slopes of 1 to 3%, often on fan terraces, sometimes with gravel/pebbles over much of the surface. It can be also found in the swales of sand dunes on grades up 10%. In finer or courser soils (either valley flats or on slopes above 3%) *Ambrosia deltoidea* becomes more common than *A. dumosa.* Upslope, creosote/white bursage grades into creosote/paloverde-ironwood. Downslope it grades into either creosote flats or creosote/triangle-leaf bursage or creosote/mesquite floodplain.

On the adjacent BLM lands to the east (Malusa, 2003), this association is found on the gravelly sandy loams and sandy loams included in the Denure-Rillito-Why complex. To a less extent, it also occurs on at least five other soils or soil complexes (Johnson, 1997), including the Gunsight-Rillito-Carrizo complex, characterized by gravelly to very gravelly loams

Field Identification: Clearly associated with the gravelly interfluves of terraces, or, downslope, "islands" of courser sediments above the finer soils in floodplains. Although there may be a few mesquites in rills, there are no paloverde (*Parkinsonia)* or ironwood (*Olneya)*. *Ambrosia deltoidea* and *Pleuraphis rigida* are absent, rare, or uncommon, with <1% cover.

Photo Identification: On the alluvial fans lacking ironwood and paloverde, particularly if they have a blue/gray cast on the near infra-red image. Further from the mountain fronts, on terraces perched slightly above the watercourses, there are often long fingers of alluvium – gravels – of the same color. These are quite mappable, and, best of all, a walk in the desert shows that they actually are gray gravels. When such gravels are lacking, the boundary between creosote/white bursage and the creosote/mesquite floodplain is often vague, because of the low relief. Areas mapped as creosote/white bursage held (a) very low densities of mesquite, or none at all; (b) no patches of dense vegetaion; and (c) no barrens.

Association: *Larrea tridentata/Ambrosia dumosa* (Creosote/White Bursage*)*

Classification: 154.111

Number of sample sites: 20

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	20	5 (4-5)	5-9% (5-25%)	1.2
Ambrosia dumosa	20	3 (2-4)	1-4% (<1-14%)	0.4
Pleuraphis rigida	17	2 (0-3)	<1% (0-4%)	0.6
Ferrocactus wislizeni	9	0 (0-2)	0 (0 to <1%)	
Ambrosia deltoidea	9	0 (0-2)	0 (0 to <1%)	
Prosopis spp	8	0 (0-3)	0 (0 to <1%)	
Krameria grayii	7	0 (0-3)	0 (0 - 4%)	
Carnegiea gigantea	6	0 (0-3)	0 (0 to <1%)	
Erioneuron pulchellum	4	0 (0-2)	0 (0 to <1%)	
Opuntia leptocaulis	3	0 (0-2)	0 (0 to <1%)	
Opuntia kunzei	2	0 (0-3)	0 (0 - 4%)	
Opuntia ramosissima	2	0 (0-3)	0 (0 - 4%)	
Opuntia spinosior	2	0 (0-1)	0 (0 to <1%)	
Opuntia acanthocarpa	2	0 (0-1)	0 (0 to <1%)	
Castela emoryi	2	0 (0-1)	0 (0 to <1%)	
Fouquieria splendens	2	0 (0-2)	0 (0 to <1%)	

Association: *Larrea tridentata/Ambrosia deltoidea* (Creosote/Triangle-leaf Bursage)

Classification: 154.112

Warren et al. classification: part of 154.1111, which, in their scheme, includes either/both *Ambrosia dumosa* and *A. deltoidea,* sub-dominant to *Larrea tridentata*.

Brown, Lowe and Pase classification: An undescribed association of the creosote-bursage series, 154.11.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: none currently listed. The association in this study is a *Larrea tridentata/Ambrosia deltoidea* sparse shrubland.

Description: Creosote is dominant, and triangle-leaf bursage common and preferring runnels or shallow depressions. White bursage and mesquite are uncommon, rare or absent. Saguaro, *Opuntia ramossissima,* and big galleta (*Pleuraphis rigida)* are occasionally common, but more often are absent, rare, or uncommon. *Parkinsonia microphylla* are present at 5 of 21 sites, but always rare – only one or two individuals. *Krameria grayii* (2 of 21 sites) and ocotillo (only 1 site) are notably lacking.

Location: At elevations of 500-1500 feet (150-460 meters). Typically on slopes of 1 to 3%, bordering areas of creosote/mesquite floodplains, or as islands within loosely braided creosote/mesquite floodplain in valley bottoms. On these shallow slopes it is found on the same soils complexes as pure creosote communities. Within the adjacent BLM lands to the east, the soils are part of the Dateland-Cuerda complex, characterized by upper surfaces (top 5 to 35 inches) of fine or very fine sandy loams, or stratified loams; and the Denure-Rillito-Why complex, which generally lies a bit further upslope, and includes soils with gravelly sandy loams and sandy loams, sometimes with pebbles over much of the surface.

Occasionally it is found in a very different place, on the lower slopes of mountains, at slopes up to 5%. Such habitat is usually home to ironwood and paloverde. If these are lacking, and creosote is still dominant or co-dominant, it was mapped within this association.

Field Identification: White bursage, mesquite and paloverde ae uncommon, rare, or absent. There was a single ironwood in all 21 sites. *Ambrosia deltoidea* does not exceed 15% cover overall. Iin contrast, it can reach 40% cover in the creosote/mesquite floodplain. Mountain slopes that lacked paloverde/ironwood, *Opuntia bigelovii,* or obvious accumulations of caliche (154.1172, below) were mapped as creosote/triangle leaf bursage or triangle leaf bursage/creosote (154.1125; see below), depending on dominance.

Photo Identification: The creosote/triangle-leaf bursage association was generally identified and mapped by what it *lacked*. There were no trees (or only one or two); it did not have the courser grain alluvial outwash associated with creosote/white bursage; it did not have the distinct regular dispersion of pure creosote flats: and it did not have the large barren areas that are often bordered the creosote/mesquite floodplain.

Association: *Larrea tridentata/Ambrosia deltoidea* (Creosote/Triangle-leaf Bursage*)*

Classification: 154.112

Number of sample sites: 21

taxon	sites	median prominence(range)	mean cover (range)	mean height (meters)
Larrea tridentata	21	5 (4-5)	5-9% (<1-25%)	1.2
Ambrosia deltoidea	21	3 (2-4)	5-9% (<1-14%)	0.5
Carnegiea gigantea	9	0 (0-3)	0 (0 to <1%)	
Ferrocactus wislizeni	9	0 (0-2)	0 (0 to <1%)	
Pleuraphis rigida	9	0 (0-3)	0 (0-1%)	
Opuntia ramosissima	9	0 (0-3)	0 (0 to <1%)	
Ambrosia dumosa	9	0 (0-2)	0 (0 to <1%)	
Prosopis spp.	8	0 (0-2)	0 (0-4%)	
Parkinsonia microphylla	5	0 (0-1)	0 (0 to <1%)	
Opuntia fulgida	3	0 (0-3)	0 (0-4%)	
Opuntia kunzei	2	0 (0-3)	0 (0 to <1%)	
Krameria grayii	2	0 (0-3)	0 (0-4%)	

Association: *Larrea tridentata/ Ambrosia dumosa—A. deltoidea*
(Creosote/White Bursage—Triangle-leaf Bursage)

Classification: 154.113

Warren et al. classification: part of 154.1111, which, in their scheme, includes either/both *Ambrosia dumosa* and *A. deltoidea,* sub-dominant to *Larrea tridentata*.

Brown, Lowe and Pase classification: An undescribed association of the creosote-bursage series, 154.11.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: none currently listed. The association in this study is a *Larrea tridentata/ Ambrosia dumosa—A. deltoidea* sparse shrubland.

Description: Creosote is dominant or co-domianant. Both species of *Ambrosia* are present, and typically common, with *A. dumosa* prevailing on the interfluves, and *A. deltoidea* in the runnels between. *Opuntia ramissisoma* and *O. leptocaulis* are present on about half the sites, and occasionally common. Mesquite and foothill paloverde don't exceed 1% cover. In contrast, *Pleuraphis rigida* and *Krameria grayii* may have up to 4% cover, despite being absent from half the sites.

Compared to the same association on the adjacent BLM lands to the east (Malusa, 2003), the most significant differences are the reduction in the size and cover of creosote on the refuge (1.35m vs. 1.2m, 10-25% cover vs. 5-9% cover), and the apearance of diamond cholla (*Opuntia ramosissoma*) on the refuge.

Location: At elevations of 1490-1800 feet (450-550 meters) on slopes of 1 to 5%, this association is usually found just downslope of the creosote/bursage/paloverde/ironwood association (154.1170). Here, below the "treeline", there are small rises of relatively course alluvium, dissected by runnels and finer soils. The result is a matrix of the *Ambrosia deltoidea* and *A. dumosa* associations. If the mapping unit were very small – say, 10 by 10 meters – it would be possible to split this association. Soils are similar to the other creosote/bursage associations (154.110, 154.111, 154.112), which include gravelly sandy loams and sandy loams, sometimes with pebbles over much of the surface (Johnson, 1997).

Field Identification: Walking perpendicular to the runnels, you encounter both species of *Ambrosia.*

Photo Identification: The characteristic pattern is thin dark lines of *A. deltoidea* in runnels that also hold an occasional mesquite. Between the runnels are the broader but more sparsely vegetated interfluves. In other words, it was a matrix of both bursage associations, and was often used as catch-all for those areas that did not cleanly fall into one or the other creosote/bursage association.

Association: *Larrea tridentata/ Ambrosia dumosa—A. deltoidea* (Creosote/White Bursage—Triangle-leaf Bursage*)*

Number of sample sites: 18

Taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	18	5 (4-5)	5-9% (5-25%)	1.2
Ambrosia deltoidea	18	3 (2-4)	1-4% (<1-14%)	0.5
Ambrosia dumosa	18	3 (2-4)	1-4% (0-9%)	0.4
Opuntia ramossisoma	11	2 (2-3)	0 (0 to <1%)	
Pleuraphis rigida	10	1-2 (0-3)	<1% (0-4%)	0.7
Carnegiea gigantea	9	0-1 (0-3)	0 (0 to <1%)	
Prosopis spp.	8	0 (0-3)	0 (0 to <1%)	
Krameria grayii	8	0 (0-3)	0 (0-4%)	0.5
Opuntia leptocaulis	7	0 (0-3)	0 (0 to <1%)	
Parkinsonia microphylla.	7	0 (0-2)	0 (0 to <1%)	
Ferrocactus wislizeni	6	0 (0-2)	0 (0 to <1%)	
Fouquieria splendens	4	0 (0-3)	0 (0 to <1%)	
Erioneuron pulchellum	3	0 (0-2)	0 (0 to <1%)	
Muhlenbergia porteri	2	0 (0-2)	0 (0 to <1%)	
Opuntia kunzei	2	0 (0-3)	0 (0 to <1%)	

Association: *Larrea tridentata—Opuntia bigelovii/Ambrosia spp.*

(Creosote—Teddy Bear Cholla/Bursage)

Classification: 154.114

Warren et al. classification: Not present at Organ Pipe Cactus NM. It was also not on the BLM lands north of Organ Pipe Cactus NM (Malusa, 2003). Because this is generally a pediment association, it can be seen as a more arid version of Warren et al.'s 154.1212, lacking paloverde and bursage as dominant species.

Brown, Lowe and Pase classification: Listed in appendix as 154.117, but undescribed..

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: none currently listed. The association in this study is a *Larrea tridentata—Opuntia bigelovii/ Ambrosia spp.* sparse shrubland.

Description: The diagnostic species for this association is teddy bear cholla, also known as jumping cholla (*Opuntia bigelovii)*. The association is similar to 154.124, the uplands rocky pediment with *Opuntia bigelovii*, but with this difference: creosote is the dominant or co-dominant species in 154.114, while bursage or paloverde are the most common in 154.124.

Carnegiea gigantea and *Opuntia acanothocarpa* are not abundant yet conspicous and present at most sites, as is *Parkisonia microphylla.* Statisically uncommon or rare but still present at about half the sites are *Krameria grayii, Olneya tesota*, and *Opuntia ramossisima;* on occasion they are common, with up to 4% cover. Likewise, *Ambrosia dumosa* is typically rare, but at one site is co-dominant with creosote. Upslope, this association can hold frost-sensitive species like *Sebastiana (=Sapium) biloculare* and *Jatropha cuneata.*

Location: At elevations of 1480-1780 feet (450-550 meters), in areas of low relief (less than 3%).

This association is downslope from the rocky pediment with *Opuntia bigelovii* (154.124), or tucked up against slopes >20%. *Opuntia bigelovii* is not frost-sensitive, and it often occurs on course alluvial outwash that carries the plant far downslope into the cold night air of the valleys. Because it's propogated asexually from its stems, pieces of cholla can be carried off by arroyos and form new populations. For example, two such areas, each about a mile long, run along the large arroyo that parallels the western foot of Childs Mountain.

Field Identification: This association was mapped by hiking along the lower limit of the teddy bear cholla *(Opuntia bigelovii)*, the diagnostic species. Binoculars were useful for spotting distant individuals, which were included in the range unless they were over one hundred meters (328 feet) from the rest of the population. The upper bounds were the 20% slope limit of the study, but the teddy bear cholla, like the palo verde and bursage, range well beyond 20%, up the steepest slopes.

Once the range of the *Opuntia* was established, the site was deemed 154.114 if creosote is the dominant or co-dominant species. (In truth, *Opuntia* is dominant in 2 of the 17 sample sites in 154.114, but in these instances creosote is still more common than either bursage or paloverde, and a better overall descriptor of the association.)

Photo Identification: Photos couldn't discern the range of *Opuntia bigelovii*, but they could be used to draw the line between the two *Opuntia bigelovii* associations, creosote/*Opuntia bigelovii* (154.114) and bursage/foothill paloverde/*Opuntia bigelovii* (154.124). In general, trees were used as a proxy for creosote dominance, using the data from the BLM lands adjacent to the east (Malusa, 2003). For instance, if paloverde and/or ironwood were common – say, over ten percent cover – then it was presumed bursage would be dominant or co-dominant, and mapped as 154.124. If the trees were uncommon, less than five percent cover, than it was presumed creosote was dominant or co-dominant. If tree cover was between five and ten percent, I tended to map the area as 154.124 – the bursage dominated association.

Association: *Larrea tridentata—Opuntia bigelovii /Ambrosia spp* (Creosote—Teddy Bear Cholla/Bursage)

Classification: 154.114

Number of sample sites: 17

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	17	5 (3-5)	5-9% (1-14%)	1.1
Opuntia bigelovii	17	3 (2-5)	1-4% (<1-4%)	0.95
Carnegiea gigantea	16	2 (0-3)	<1% (0 to <1%)	
Ambrosia deltoidea	15	3 (0-4)	1-4% (0-9%)	0.5
Parkinsonia microphylla	15	2 (0-3)	1-4% (0-4%)	3.2
Opuntia acanthocarpa	14	2 (0-3)	<1% (0-4%)	
Fouquieria splendens	13	2 (0-3)	<1% (0 to <1%)	
Krameria grayii	10	2 (0-3)	<1% (0-4%)	0.4
Olneya tesota	10	1 (0-3)	<1% (0-4%)	2.5
Ambrosia dumosa	9	1 (0-4)	<1% (0-4%)	
Opuntia ramosissima.	8	0 (0-3)	0 (0 to <1%)	
Opuntia fulgida	7	0 (0-5)	0 (0-14%)	
Echinocereus nicholii	6	0 (0-2)	0 (0 to <1%)	
Encelia farinosa	4	0 (0-3)	0 (0 to <1%)	
Krameria erecta	3	0 (0-3)	0 (0 to <1%)	
Sebastiana biloculare	2	0 (0-1)	0 (0 to <1%)	
Jatropha cuneata	2	0 (0-2)	0 (0 to <1%)	
Ferrocactus emoryi	1	0 (0-1)	0 (0 to <1%)	
Ferrocactus cylindraceus	1	0 (0-1)	0 (0 to <1%)	

Association: *Larrea tridentata/Prosopis velutina-P. glandulosa* floodplain (Creosote/Mesquite floodplain)

Classification: 154.115

Warren et al. classification: 154.1115R

Brown, Lowe and Pase classification: An undescribed association of the creosote-bursage series, 154.11.

NVCS alliance: There is a *Larrea tridentata* shrubland alliance currently in the database; the alliance in this study straddles the line between *Larrea tridentata* sparse shrubland (with the "sparse" indicating less than 25% cover), and *Larrea tridentata* shrubland (25-60% cover).

NVCS association: The closest parallel is a *Larrea tridentata - Prosopis glandulosa* Shrubland listed from the Chihuahuan desert in New Mexico and Texas, but not Arizona. Possibly related, too, is the *Larrea tridentata / Lycium andersonii - Grayia spinosa* Shrubland described from the Mohave desert of Nevada and perhaps California.

Description: This association is found where occasional sheet flooding has allowed the growth of scattered mesquite and wolfberry (*Lycium* spp.) in an area otherwise characterized by creosote. Statistically, creosote is typically co-dominant (and big, with a median height of 1.8m), with mesquite common and *Lycium* spp. uncommon. However, as indicated in the range of "prominence" in the table below, there is wild variation, with *Lycium* sometimes co-dominant, and sometimes absent. Likewise, *Ambrosia deltoidea*, present at 23 of 28 sites, and *Pleuraphis rigida,* at 15 sites, were occasionally the dominant species. *Hymenoclea salsoa,* at only 4 sites, was co-dominant at 3, with up to 9% cover. Present in less than half the sites, but occasionally common, were *Parkinsonia floridum, Muhlenbergia porteri, Pleuraphis rigida, Olneya tesota, and Ambroisa confertiflora.* Annuals such as *Kalistroemia grandiflora* and various Malvaceae formed dense patches during wet years.

Floodplains lack a well-defined channel. They often border large arroyos (beds wider than 5 meters/16 feet) that occasionally breach their banks. But floodplains, as defined here, also occur along valley bottoms in a variety of creosote or creosote/bursage associations that lack distinct watercourses.

There were also largely barren areas associated with floodplains. They were included within this association because they held dead or small *Lycium, Prosopis, Hymenoclea,* or *Parkinsonia floridum.* Often it was just a few plants, but these are species that are typical of the denser growth of the floodplain, and not the creosote/bursage desert beyond. They are more correctly referred to as *former floodplain,* but are mapped here as part of the floodplain. Bordering very large arroyos, there are occasionally large areas of dead or dying floodplain species, and it is easy to imagine that they took root during better times.

Location: At elevations of 1480-1780 feet (450-550 meters), in areas of low relief (less than 3%). Wherever there are creosote or creosote/bursage associations, there may

be creosote/mesquite floodplains. In contrast, where the drainages are between slopes holding foothill palo verde (*Parkinsonia microphylla*) or ironwood (*Olneya tesota*), this association is typically replaced with arroyos with well-defined channels (154.1214, 154.181; see below). In general, this means that floodplain associations are more common towards the valley bottoms. But they can also be upslope, as islands within braided arroyos, and they can even toe up against a steep mountain slope. For example, a large flat that abuts the north side of Childs Mountain is characterized by about 10-14% cover of 2.5 meter mesquite and little else.

Field Identification: *Prosopis, Lycium, Ambrosia* and *Hymoclea* are the key species. If *Prosopis* is uncommon or *Lycium* was absent, then dense patches (cover greater than 25%) of *Larrea* or *Ambrosia deltoidea* sufficed to define the association. As mentioned above, the largely barren areas bordering denser vegetation were included in this association. So were virtually or completely barren areas, if adjacent to floodplains, as is common in the Growler and San Cristobal Valleys, because they appear to be abandoned channels among many vague channels.

When creosote/mesquite habitat bordered large watercourses, it was mapped as floodplain if the proportion of creosote or bursage exceeded that of mesquite or palo verde trees.

Photo Identification: Along major drainages (bed wider than 5m) in the valley bottoms, the floodplain was not the essentially continuous line of vegetation bordering the channel, nor was it the surrounding associations of relatively homogeneous creosote or creosote/bursage. It was different: a barren, or largely barren but speckled with what appeared to be large creosote or small mesquite. With very large arroyos in the center of valley bottoms there is an obvious soil difference between the floodplain and the surrounding drylands: the floodplain is darkened with bands parallel to the main channel.

Many small channels/arroyos are also fringed by a strip of floodplain, but for the purposes of this study the strip had to be at least 10 meters wide (33 feet) to be mapped as separate from the arroyo.

In areas where there is no drainage whatsoever with a defined channel, floodplain was typically recognized by barrens and the swaths of dots that are *Prosopis* or large *Larrea;* areas lacking the barrens but with a clear line of trees were also mapped. The patches of creosote or creosote/bursage within the floodplain were mapped if they were larger than 100 m square, or one hectare.

Upslope floodplains – those not in the creosote flats, but in the mountain foothills, amid foothill paloverde and ironwood – are difficult to place in this simple system of a single “floodplain” association. The floodplains of large mountain arroyos are more diverse than their valley counterparts, and perhaps should be given their own association/identity. Lacking this, I mapped them within the same association as the valley floodplain. They were identified as such if, relative to the main channel and the surrounding hillsides, there were fewer trees and more creosote and *Ambrosia deltoidea*.

Finally, floodplains often grade into and out of drainages with well-defined channels. When the channel bed was no longer visible on the photo, the drainage was mapped as floodplain. This probably exaggerates the extent of floodplain, because overhanging vegetation can obscure the channel.

Association: *Larrea tridentata/Prosopis velutina-P. glandulosa* floodplain (Creosote/Mesquite floodplain)

Classification: 154.115

Number of sample sites: 28

Taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	28	4 (2-5)	10-14% (<1 to 60%)	1.8
Prosopis spp.	26	3 (0-5)	5-9% (0 - 40%)	3.5
Ambrosia deltoidea	23	3 (0-5)	5-9% (0 - 60%)	0.6
Lycium spp.	18	2 (0-4)	<1% (0 – 9%)	1.3
Pleuraphis rigida	15	1 (0-5)	0 (0 to 60%)	0.9
Ambrosia dumosa	9	0 (0-4)	0 (0 to 9%)	0.45
Amaranthus palmeri	8	0 (0-3)	0 (0 to <1%)	
Parkinsonia floridum	8	0 (0-3)	0 (0 to 9%)	
Ferrocactus wislizeni	7	0 (0-2)	0 (0 to <1%)	
Acacia greggii	6	0 (0-3)	0 (0-4%)	
Carnegiea gigantea	5	0 (0-1)	0 (0 to <1%)	
Opuntia leptocaulis	5	0 (0-3)	0 (0 to <1%)	
Olneya tesota	4	0 (0-3)	0 (0 – 4%)	3.5
Hymonoclea salsoa.	4	0 (0-4)	0 (0 – 9%)	
Castela emoryi	3	0 (0-2)	0 (0 to <1%)	
Ziziphus obtusifolia	2	0 (0-2)	0 (0 to <1%)	
Ambrosia confertiflora	2	0 (0-3)	0 (0 to <1%)	
Muhlenbergia porteri	1	0 (0-3)	0 (0 to <1%)	

Association: *Larrea tridentata/Pleuraphis rigida* (Creosote/Big Galleta Grass)

Classification: 154.116

Warren et al. classification: Not classified, but they reported *Hilaria rigida (=Pleuraphis rigida)* to be found in 4 of 12 sites in their 154.1115R (creosote/mesquite floodplain), and in 4 of their 41 sites of their 154.1112 (creosote/bursage with occasional paloverde and ironwood).

Brown, Lowe and Pase classification: Not classified. However, Turner and Brown (1982) suggest that *Larrea tridentata*/*Pleuraphis rigida* is a series of the Lower Colorado Subdivision of the Sonoran Desert.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover. There is also a *Pleuraphis rigida* Shrub Herbaceous Alliance in the database, but with no data to back it up.

NVCS association: There is no similar association. The closest parallel is the *Ambrosia dumosa / Pleuraphis rigida* Dwarf-shrubland association from sand dunes; however, this association lacks *Larrea tridentata* as the co-dominant/dominant species.

Description: On low and sandy swales, *Larrea tridentata* is co-dominant to dominant, while *Pleuraphis rigida* is common (rarely, it may be locally dominant). *Ambrosia dumosa* is at 20 of 27 sites, with a median prominence of common. *Krameria grayii* is at only 14 sites, but common at 9 of those 14. Because it's missing from so many sample sites, its median prominence is "rare. These two species, *Ambrosia dumosa* and *Krameria grayii*, make up 15-20% of pronghorn scat during dry summers and dry winters (Hervert et al., 2000).

Perennials present at one-third or less of the sites yet occasionally deemed "common" include ocotillo (*Fouquieria splendens)*, *Prosopis spp.,* and a remarkable 6 species of *Opuntia.* One of these, *O. kunzei*, was present at only four sites, yet ranked a codominant at one these sites, in the O'Neil Hills. .

Location: On slopes of 1 to 10%. The steeper slopes are not hillsides, but instead rolling swales. They can be sandy or of much finer grain – almost like loess, and very likely windblown. This association is also on fan terraces above the Growler Wash, and in places that would appear, at first glance, to be creosote flats. They *are* creosote flats, but they surround islands of *Pleuraphis rigida*. Along Daniel's Arroyo, for example, there are at least three creosote flats, each over a mile across, that are in fact at least 25% *Larrea trindentata/Pleuraphis rigida* – you just can't see it from the edge.

The soil map of the BLM lands to the east show this association on the Denure-Coolidge complex, whose top 2-4 inches is typically a gravelly to very gravelly, sandy to very-fine sandy loam. This association also occurs on the Dateland-Cuerda complex, soils more typical of flood plains, and characterized by upper surfaces (up to 35 inches deep) of fine or very fine sandy loams, or stratified

loams. And, finally, it also occurs on the Gunsight-Rillito-Carrizo complex, characterized by gravelly to very gravelly loams.

Field Identification: While mapping the BLM lands to the east (Malusa, 2003), my sole requirement for this association was that *Pleuraphis rigida* was common, with a cover of at least 5%. For the refuge, where there's less rain and fewer plants, the requirement is a cover of 1-4%. Keep in mind, also, that in this association creosote must be dominant or co-dominant. If *Ambrosia dumosa* and/or *Pleuraphis rigida* are dominant, it is the sand dune association described below (154.126). Occasionally, it is common in shallow watercourses, with *Lycium* and other arroyo species; these occurrences of *Pleuraphis* were not included in this association, but included in one of the arroyo associations. Likewise, when there are dense patches of *Pleuraphis* in vague channels, these were included in the floodplain association.

Photo Identification: The wind-blown sands that are favored by *Pleuraphis rigida* are visible as a "smear" on the photographs. On the satellite image marketed by "Above and Beyond" (dohrenwedn@rkymtnhi.com) and titled "Organ Pipe Cactus National Monument", the creosote/big galleta association is pink, probably because the sands are often pink. Otherwise, the pattern of vegetation is similar to a creosote flat, with regular dispersion between the plants, particularly when the vegetation is almost entirely creosote and big galleta grass.

Association: *Larrea tridentata*/*Pleuraphis rigida* (Creosote/Big Galleta Grass)
Classification: 154.116
Number of sample sites: 27

Taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	27	4 (3-5)	5-9% (2-25%)	1.5
Pleuraphis rigida	27	3 (3-5)	5-9% (2-40%)	0.6
Ambrosia dumosa	20	3 (0-4)	1-4% (0 to <14%)	0.4
Krameria grayii	14	1 (0-3)	<1% (0-4%)	0.6
Fouquieria splendens	12	0 (0-3)	0 (0 to <1%)	
Ferrocactus wislizeni	12	0 (0-2)	0 (0 to <1%)	
Prosopis spp.	9	0 (0-3)	0 (0 - 15%)	
Opuntia leptocaulis	9	0 (0-3)	0 (0 – 4%)	
Opuntia acanthocarpa	7	0 (0-3)	0 (0 to <1%)	
Opuntia fulgida	7	0 (0-3)	0 (0 to <1%)	
Opuntia ramosissima	6	0 (0-3)	0 (0 – 4%)	
Opuntia kunzei	4	0 (0-4)	0 (0 – 9 %)	
Opuntia echinocarpa	4	0 (0-3)	0 (0 to <1%)	
Parkinsonia microphylla	4	0 (0-1)	0 (0 to <1%)	
Ambrosia deltoidea	4	0 (0-2)	0 (0 to <1%)	
Erioneuron pulchellum	3	0 (0-3)	0 (0 to <1%)	
Muhlenbergia porteri	1	0 (0-2)	0 (0 to <1%)	

Association: *Larrea tridentata/Ambrosia deltoidea-Krameria grayii* with less than 10% cover of *Parkinsonia microphylla-Olneya tesota* (Creosote/bursage/ratany with <10% cover of palo verde/ironwood)

Classification: 154.1170

Warren et al. classification: Most similar to 154.1112, which is described as a "middle bajada" association, with *Parkinsonia microphylla (=Cercidium microphylla)* present at 25 of 41 sites. In the present study's scheme, however, *Parkinsonia microphylla* or *Olneya tesota* must be present to be included in this association, so this association would not include the treeless habitat in Warren et al.'s 154.1112.

Brown, Lowe and Pase classification: The "mixed-scrub" series of the Lower Colorado Subdivision mentioned by Turner and Brown (1982) is clearly different, with a "poorer representation or absence of Little-leaf Palo Verde" (*Parkinsonia microphylla)* and *Ambrosia deltoidea* "conspicuously lacking." Both of these species are characteristic of the association described below. Hence, in a BLP classification, this would be an undescribed association of the creosote-bursage series, 154.11.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: No similar association within the *Larrea* alliance.

Description: *Larrea tridentata* is the most abundant species, with the highest median prominence (5) and cover (5-9%). The association is nonetheless recognized by the presence of foothill palo verde (*Parkinsonia microphylla)* and ironwood (*Olneya tesota)* at a combined cover of less than 10%, and usually much less – the median cover of palo verde is 1-4%, while the ironwood is less than 1%.

More common were *Ambrosia deltoidea* (present at 35 of the 38 sample sites), *Ambrosia dumosa* (29 of 38 sites, and co-dominant species at 7 sites), and *Krameria grayii* (35 sites). These two species comprise 15-20% of pronghorn scat during dry summers and dry winters (Hervert et al., 2000). Each species typically provides 1-4% cover in this association.

Cacti are conspicuous. *Carnegiea gigantea* was at 36 of 38 sites, *Opuntia fulgida* was at 25 sites, and *O. acanthocarpa* was at 27 sites. *O. leptocaulis* and *Opuntia ramossisimia* are at 16 and 11 sites, respectively. are each found on at least half of the sites. *Ferrocactus emoryi* and *Echinocereus nicholii* are each at 10 sites.

The most common grasses are *Erioneuron pulchellum* (9 sites) and *Pleuraphis rigida* (11 sites); they are occasionally common, but more often uncommon, rare or absent

Location: On slopes of 2 to 20% (the upper limit of this study). *Parkinsonia microphylla* and *Olneya tesota* apparently prefer slopes and courser outwash materials from the mountains. On the adjacent BLM lands to the east, they are most commonly found on soils of the Gunsight-Rillito-Carrizo complex; also common are the Gunsight-Cipriano complex and the Gunsight-Chuckwalla complex. The recurring element of the three complexes is Gunsight soils, which

are characterized by extremely gravelly loams and a very limy layer at a depth of 5 to 24 inches. Such soils are generally close to the mountain fronts, but occasionally are transported far into the valleys. For example, there is a large outwash of alluvium from Copper Canyon and associated arroyos reaching at least five miles beyond the mountains, northwest, ultimately reaching Daniel's Arroyo.

Field Identification: At its lower elevational limit, this association grades into creosote/bursage communities, so it is easy enough to draw the line where the Parkinsonia microphylla and/or Olneya tesota become conspicuous. When mapping the limits of a large population, the lower bounds were drawn to include the very lowest trees, unless there were over 100 meters (330 feet) separating the tree from the rest of the population. For small, outlying populations of these trees, there must be at least 10 individuals in a 100-meter square to be mapped.

At its upper limit this association abuts either "Arizona upland" or pediment associations. Uplands (154.122) are distinguished by the co-dominance or dominance of *Ambrosia*, which is correlated with a *Parkinsonia microphylla* and *Olneya tesota* cover of greater than 10%, as measured on the ground. Pediment associations were generally recognized by the presence of a particular species -- *Stenocereus thurberi* or *Opuntia bigelovii* – and were mapped in the field. The exception is a "new" association – i.e., found on the refuge but not on the BLM lands to the east – called 154.125 (see below). Like the *Larrea* association described here, it too has few palo verde and ironwood, but the new association is *Ambroisa* dominant or co-dominant. It is typically restricted to steeper slopes that lack *Opuntia bigelovii*, because they're north-facing, or buttes and ridges isolated by teddy bear cholla-unfriendly habitat, like floodplains.

Photo Identification: *Parkinsonia microphylla* and *Olneya tesota* are generally easy to identify on the photos. At their lower limits they can be confused with mesquite (*Prosopis)*, but the latter prefers watercourses or flats while the former prefers slopes. As for the upper limit of this association, it was a matter of determining the appearance – i.e., the density of dots – of places where field surveys had shown a combined tree cover equal to or greater than 10%. On the BLM lands to the east (Malusa, 2003), this cover value for the trees serves as a proxy for determining the relative abundances of the *Larrea tridentata* and *Ambrosia deltoidea* from the photographs. In general, where the combined cover of palo verde and ironwood is less than 10%, *Larrea* is either more common than *A. deltoidea*, or co-dominant with it. Where tree cover exceeds 10%, *A. deltoidea* is generally more common than *Larrea* (see 154.121). On the refuge, the dividing point needs to be modified to perhaps 5% cover as one moves west into more arid lands, where *Ambrosia* dominated hillsides have fewer trees.

Association: *Larrea tridentata*/*Ambrosia deltoidea-Krameria grayii* with less than 10% cover of *Parkinsonia microphylla-Olneya tesota* (Creosote/bursage/ratany with <10% cover of palo verde/ironwood)

Classification: 154.1170

Number of sample sites: 38

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	38	5 (4-5)	5-9% (1 -25%)	1.2
Parkinsonia microphylla	38	2 (2-4)	1-4% (<1% to 9%)	3.3
Carnegiea gigantea	36	2 (0-3)	<1% (0 to <1%)	
Ambrosia deltoidea	35	3 (0-4)	1-4% (0-14%)	0.45
Krameria grayii	35	3 (0-3)	1-4% (0-4%)	0.5
Ambrosia dumosa	29	3 (0-4)	1-4% (0-14%)	0.4
Olneya tesota	27	2 (0-4)	<1% (0-9%)	3.2
Opuntia acanthocarpa	27	2 (0-3)	<1% (0 to <1%)	
Fouquieria splendens	26	2 (0-3)	<1% (0 to <1%)	
Opuntia fulgida	25	2 (0-3)	<1% (0-4%)	
Opuntia leptocaulis	16	0 (0-3)	0 (0 to <1%)	
Opuntia ramosissima	11	0 (0-3)	0 (0 to <1%)	
Pleuraphis rigida	11	0 (0-3)	0 (0 to 4%)	
Echinocereus nicholii	10	0 (0-1)	0 (0 to <1%)	
Ferrocactus emoryi	10	0 (0-2)	0 (0 to <1%)	
Erioneuron pulchellum	9	0 (0-3)	0 (0 to <1%)	
Krameria erecta	8	0 (0-3)	0 (0–9%)	0.4
Prosopis spp.	4	0 (0-2)	0 (0 to<1%)	
Muhlenbergia porteri	4	0 (0-2)	0 (0 to <1%)	

SubAssociation: *Larrea tridentata/Ambrosia deltoidea-Krameria grayii* on pavements, with <5% cover of *Parkinsonia microphylla-Olneya tesota* (Creosote/bursage on pavements, with <5% cover of palo verde/ironwood)

Classification: 154.1171 (a sub-association of 154.117)

Warren et al. classification: Not present at Organ Pipe Cactus NM. It was also not on the BLM lands north of Organ Pipe Cactus NM (Malusa, 2003). Because this is generally a pediment association, it can be seen as a more arid version of Warren et al.'s 154.1212, lacking paloverde and bursage as dominant species.

Brown, Lowe and Pase classification: An undescribed association of the creosote-bursage series, 154.11.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: No similar association within the *Larrea* alliance.

Description: At the foot of mountains, on alluvial fans much dissected by runnels. The diagnostic feature is nude interfluves – nothing but an expanse of small stones between the runnels. Usually the stones are desert pavements, neatly spaced and tightly packed stones, but occasionally they are a bit sloppier and looser but nonetheless devoid of vegetation. This association More than 50% of the soil surface is devoid of vegetation. The plants live in the runnels, or at the edges of runnels.

This association can be described as a subassociation of 154.1170 (see above). The species of this association are essentially the same as in typical 154.1170, and in the same proportions, too. Creosote is typically dominant or co-dominant, with triangle-leaf bursage and white bursage a close second and third. Foothill paloverde and *Krameria grayii* are also common. The median cover, however, is significanly less in this pavements subassociation – the summed cover of all species is often around 5%.

Location: On slopes of 2-10%, this this association can be found on soils derived from any rock type on the range. The key ingredients in forming nude interfluves appear to be (1) a debris flow from a mountain canyon to eject a fan of course sediments; and (2) aridity on the order of less than seven inches annually.

Field Identification: The surface is at least 50% devoid of vegetation. Obviously, most every site on the Cabeza Prieta NWR is, at some level, more than 50% devoid of vegetation. But in this association can you walk perpendicular to the drainages and count off numbers like so: 7 paces past creosote and bursage, then 23 paces of nothing but nude pavements, then 10 of vegetation, and 29 without, and so forth. The pacing is necessary not only to determine if the extent of the pavements, but to later determine the overall percent cover of the species. Some places near the Mohawk Mountains were 80% nude pavements.

Photo Identification: After visiting a few locations in the field, it's fairly easy to spot this subassociation on the photos – it looks like it sounds, broad bands of stoney interfluves striped with vegetation.

Classification: 154.1171

Number of sample sites: 8

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	8	4 (4-5)	1-4% (1-9%)	1.1
Parkinsonia microphylla	8	2-3 (1-3)	<1% (<1% – 4%)	2.2
Ambrosia dumosa	8	3 (2-2)	1-4% (<1% – 4%)	
Ambrosia deltoidea	7	3-4 (0-4)	1-4% (0-4%)	0.4
Krameria grayii	7	3 (0-3)	<1% (0-4%)	0.5
Carnegiea gigantea	7	2 (0-3)	<1% (0 to <1%)	
Olneya tesota	6	2 (0-3)	<1% (0 – 4%)	
Fouquieria splendens	5	1-2 (0-3)	<1% (0 to <1%)	
Opuntia acanthocarpa	4	0-1 (0-3)	<1% (0 to <1%)	
Encelia farinosa	4	0-1 (0-2)	<1% (0 to <1%)	
Opuntia ramosissima	3	0 (0-3)	0 (0 to <1%)	
Opuntia fulgida	2	0 (0-3)	0 (0 to <1%)	
Echinocereus nicholii	2	0 (0-1)	0 (0 to <1%)	
Erioneuron pulchellum	2	0 (0-2)	0 (0 to <1%)	
Krameria erecta	2	0 (0-3)	0 (0 to <1%)	

SubAssociation: *Larrea tridentata/Ambrosia deltoidea-Krameria grayii* on caliche, with <10% cover of *Parkinsonia microphylla-Olneya tesota* (Creosote/bursage on caliche, with <10% cover of palo verde/ironwood)

Classification: 154.1172 (a sub-association of 154.117)

Warren et al. classification: Most similar to 154.1113, which is found "on level ridgetops and interfluves in the upper bajada from 1,400 to 2,000 feet....fragments of caliche on commonly scattered abundantly on the soil surface." However, there is very little data given by Warren et al. (1981), with no sample size, and all that can be stated for certain is that the same species occur, in similar proportions, in their 154.1113 and the association described below.

Brown, Lowe and Pase classification: An undescribed association of the creosote-bursage series, 154.11.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover.

NVCS association: No similar association within the *Larrea* alliance.

Description: More than 50% of the soil surface is fragments or chunks of caliche, a soil cement composed mainly of calcium carbonate. It is also known as hardpan. The caliche can be an ankle-twisting jumble. *Larrea* is dominant, or co-dominant with *Ambrosia deltoidea,* with a thin cover of palo verde and/or ironwood (*Parkinsonia microphylla/Olneya tesota).* This association can be described as a subassociation of 154.117 (see previous association). The key difference is that many species (save the *Larrea, A. deltoidea,* and *Krameria grayii)* are less abundant on caliche, and often stunted (the palo verde are 0.7 m/28 inches shorter when on caliche). Also noteworthy of the caliche association are the paucity of *Ambrosia dumosa* – rare on 1 of 4 samples, and absent from the other 3 – and the scarcity of *Opuntia bigelovii* and *Stenocereus thurberi* (organ pipe cactus). (A similar pattern is noted for *Opuntia bigelovii* by McAuliffe (1999), who documents a decrease in its abundance when comparing quartzite to limestone in the Waterman Mountains.)

Small watercourses torn through the caliche are often clogged with unusually dense *Acacia constricta.* On the steeper slopes above (or in) an arroyo, the caliche may be fractured and carried away by a watercourse. Here the plants are larger and, if high above the valley floor, organ pipe cactus may appear – i.e., the association is typical 154.1170 or 154.122 (pediment). The change might be due to an increase in the water availability, or decrease in caliche, or both.

The western end of the road to Charlie Bell Pass from Ajo passes along the edge of a caliche terrace. It is difficult to ignore, on foot or on wheels.

Location: On slopes of 3 to 10%. This association is only on basalts, and absent from the metamorphic and intrusive igneous rocks. On the BLM lands just east of the refuge, this association is most commonly on soils of the Gunsight-Cipriano

complex, the Cipriano-Hyder-Rock Outcrop complex, and the Cherioni very cobbly fine sandy loam (Malusa, 2003). Cipriano and Cherioni soils are described as "on nearly level to moderately steep volcanic mountains and hills. They are formed in alluvium and colluvium derived dominantly of basalt. Typically, 50 to 85 percent of the surface is covered with pebbles, cobbles, stones, and hardpan fragments. The soils are very gravelly and loamy. They are underlain by hardpan at a depth of 6 to 20 inches." (p. 7, Johnson, 1997).

Field Identification: The surface is at least 50% caliche fragments, from pea-sized to shoe-sized.

Photo Identification: Caliche is pale gray or white, even on the photos. It easy to spot, particularly when set against dark basalt slopes. Comparison of field notes and photos is the only way to later assess, with a photo alone, how much of a surface is composed of caliche.

Association: *Larrea tridentata/Ambrosia deltoidea-Krameria grayii* on caliche, with <10% cover of *Parkinsonia microphylla-Olneya tesota* (Creosote/bursage on caliche, with <10% cover of palo verde/ironwood)

Classification: 154.1172

Number of sample sites: 4

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Larrea tridentata	4	4-5 (4-5)	5-9% (5-14%)	1.3
Ambrosia deltoidea	4	3-4 (3-4)	1-9% (<1-9%)	0.4
Krameria grayii	4	2 (2-3)	<1-4% (<1-4%)	
Parkinsonia microphylla	4	2 (2-3)	<1-4% (<1-4%)	2.6
Opuntia fulgida	4	2-3 (2-3)	<1%(<1-4%)	
Carnegiea gigantea	4	2 (2)	<1% (<1%)	
Fouquieria splendens	4	2 (2-3)	<1% (<1%)	
Opuntia acanthocarpa	4	2 (2-3)	<1% (<1%)	
Echinocereus nicholii	2	0-1 (0-1)	<1% (0 to <1%)	
Opuntia leptocaulis	2	0-2 (0-3)	<1% (0 to <1%)	
Opuntia engelmanii	2	0-1 (0-2)	<1% (0 to <1%)	
Olneya tesota	2	1 (0-3)	<1% (0 – 4%)	
Ferrocactus emoryi	2	0-2 (0-2)	<1% (0 to <1%)	
Ambrosia dumosa	1	0 (0-1)	0 (0 to <1%)	
Opuntia ramosissima	1	0 (0-3)	0 (0 to <1%)	

Association: *Ambrosia deltoidea/ Larrea tridentata/Parkinsonia microphylla-Olneya tesota* (Bursage/creosote/paloverde-ironwood "Arizona upland")

Classification: 154.121

Warren et al. classification: 154.1211

Brown, Lowe and Pase classification: 154.121 *Ambrosia deltoidea-Parkinsonia microphylla* mixed scrub association of the Paloverde-mixed cacti ("Arizona Upland") series (154.12)

NVCS alliance: *Ambrosia deltoidea* shrubland. It could also fall into the *Parkinsonia microphylla* shrubland, if the trees are dominant; however, the current NVCS description of the *Parkinsonia microphylla* shrubland does not even mention the presence of *Ambrosia deltoidea,* which is dominant or co-dominant in the association described below. Further, the NVCS *Parkinsonia microphylla* shrubland has no *Carnegia gigantea,* which is omnipresent and common in the association described below.

NVCS association: No similar association yet described within the *Ambrosia deltoidea* alliance. I suggest *Ambrosia deltoidea/ Larrea tridentata*/*Parkinsonia microphylla-Olneya tesota* shrubland.

Description: Foothills palo verde and/or ironwood (*Parkinsonia microphylla/Olneya tesota)* form an overstory of typically 10% cover. *Ambrosia deltoidea* is generally the dominant shrub, with *Larrea* common and occasionally co-dominant. *Krameria erecta* was co-dominant at 1 of the 9 sample sites, and *Ambrosia dumosa* was co-dominant at 2 of the 9.

Conspicuous cactus include *Opuntia fulgida* and *Carnegiea gigantea* (at all 9 sample sites), and *O. acanthocarpa* (8 of 9). *Ferrocactus emoryi, Echinocereus nicholii, E. engelmennii, and O. leptocaulis* are on at least one third of the samples. The only grass that was abundant enough to be ranked "common" was *Erioneuron pulchellum.*

Location: At elevations of 1540-2000 feet (470-610 meters), on slopes of 5 to 20% (the upper limit of this study), on middle and upper bajadas (alluvial fans) that are usually much dissected by arroyos. These arroyos are too small to be mapped – they're more like creases in the hills – but they are a hallmark of this association. In some places, like the south flank of Black Mountain, there is Arizona Upland on the slopes, but a stripe of treeless creosote/bursage association along the ridgeline, where there is apparently not enough runoff.

Most of this association occurs on soils mapped as either the Gunsight-Rillito-Carrizo complex, or the Hyder-Gachado-Gunsight extremely gravelly loams. The comment element, Gunsight soils, are extremely gravelly and loamy and are underlain by a very limy layer at a depth of 5 to 24 inches. Around 40 to 70 percent of the surface is pebbles.

On the north side of the Little Ajo Mountains, this association is found on the Quilotosa-Momoli-Carrizo complex and the Quilotosa-Rock Outcrop complex.

Quilotosa soil is very shallow and with a surface that is 50 to 90 percent pebbles, cobbles, stones and boulders. It is derived mainly from granite and gneiss.

Field Identification: The dominant or co-dominant is usually *Ambrosia deltoidea* or *Parkinsonia microphylla*, and occasionally *A. dumosa* or *Krameria grayii*. *Larrea tridentata* is not dominant. Downslope, this association grades into 154.117, a similar association, but with *Larrea* dominant, and less tree cover (<10% combined cover for palo verde and ironwood). Upslope, it grades into pediment associations holding either the frost-sensitive organ pipe cactus (*Stenocereus thurberi)*, or *Opuntia bigelovii*, both of which were mapped on the ground.

Photo Identification: The lower limit was based simply on the apparent density of trees, using a cutoff of 10% combined cover for foothill palo verde and ironwood (the two are indistinguishable on the photos). As for the upper limit, it was either the 20% slope limit of the study, or the occurrence of the pediment species. The latter were not visible on the photos, and were drawn by hand, in the field.

Association: *Ambrosia deltoidea/ Larrea tridentata*/*Parkinsonia microphylla-Olneya tesota* (Bursage/creosote/paloverde-ironwood "Arizona upland")

Classification: 154.121

Number of sample sites: 8

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Ambrosia deltoidea	8	3-4 (2-5)	10-14% (1- 25%)	0.5
Parkinsonia microphylla	8	4 (3-4)	5-14% (1-25%)	4.0
Larrea tridentata	8	3 (2-4)	1-9% (<1-14%)	1.3
Olneya tesota	8	2-3 (1-4)	1-9% (<1-14%)	3.0
Carnegiea gigantea	8	2 (2-3)	<1% (<1%)	
Opuntia acanthocarpa	8	2 (1-3)	<1% (<1%)	
Opuntia fulgida	7	2 (0-3)	<1% (0 to<1%)	
Ambrosia dumosa	6	3 (0-4)	1-4% (0 to 9%)	
Krameria grayii	6	2 (0-4)	<1% (0 to 4%)	
Fouquieria splendens	6	2 (0-3)	<1% (0 to <1%)	
Lycium spp (berlandieri?)	5	1 (0-3)	0 (0 to 4%)	
Echinocereus nicholii	5	1 (0-1)	<1% (0 to <1%)	
Acacia constricta	4	0-1 (0-3)	<1% (0 to <1%)	
Encelia farinosa	3	0 (0-4)	0 (0 to 14%)	
Krameria erecta	3	0 (0-2)	0 (0 to <1%)	
Ferrocactus emoryi	3	0 (0-1)	0 (0 to <1%)	
Opuntia leptocaulis	2	0 (0-1)	0 (0 to <1%)	
Erioneuron pulchellum	2	0 (0-3)	0 (0 to <1%)	
Opuntia bigelovii	2	0 (0-3)	0 (0 to <1%)	
Ephedra aspera	2	0 (0-2)	0 (0 to <1%)	
Sebastiana biloculare	2	0 (0-2)	0 (0 to <1%)	
Echinocereus engelmannii	1	0 (0-1)	0 (0 to <1%)	

Association: *Ambrosia deltoidea/Larrea tridentata-Lycium spp/Parkinsonia spp* along watercourses with beds less than 5m wide (Bursage/Creosote/Wolfberry/Palo Verde)

Classification: 154.1214R (a subassociation of 154.121)

Warren et al. classification: 154.1214R

Brown, Lowe and Pase classification: Not described.

NVCS alliance: Currently not described, but would likely fall under the "formation" (the level *above* alliance in the NVCS hierarchy) of "Intermittently flooded extremely xeromorphic deciduous subdesert shrubland (III.B.3.N.b)" "Intermittently flooded" means that the "Substrate is usually exposed, but surface water present for variable periods without detectable seasonal periodicity. This modifier was developed for use in arid Western United States to describe water regimes of playa lakes, and will apply to other areas as well. Inundation is not predictable to a given season and is dependent upon highly localized rainstorms. Playa lakes, intermittent streams, and dry washes are only considered to be wetland if they support hydrophytes and/or have hydric soils."

For example, the NCVS describes two Sonoran/Mohave desert alliances closely related to the one described here. (1) The *Hyptis emoryi* (desert-lavender) Intermittently Flooded Shrubland Alliance, which is diagnosed by a tall-shrub layer with cover of *Hyptis emoryi* that is over 5% and exceeds the cover of any other shrub (Keeler-Wolf and Thomas 2000); and (2) The *Psorothamnus spinosus* (smokethorn) Intermittently Flooded Shrubland Alliance, characterized by an open, xeromorphic, tall-shrub layer (3-5 m tall) that is dominated by *Psorothamnus spinosus*.

NVCS association: Not described. I suggest " *Ambrosia deltoidea/Larrea tridentata* Intermittently Flooded Shrubland." (Total cover of shrubs is 25-60%).

Description:

note that all species except enfa that are present at just six or more sites of nineteen, are co-dominant at one site or more.

Along watercourses (known as washes or arroyos) with beds less than five meters (16 feet) wide, *Larrea* and *Ambrosia deltoidea* are most always present, and typically common. If the various species of *Lycium* are lumped into a single category, they are also omnipresent and common; likewise, if the two species of palo verde are lumped, *Parkinsonia* are omnipresent and common.

Beyond these four taxa, diversity is the hallmark, as revealed in the range of prominence values. There are ten species, for example, whose prominences range from absent to co-dominant. In other words, a species like *Bebbia juncea* (sweetbush) is absent at most sites, but is co-dominant or common at another site. The species that was dominant at the most sites – 5 of the 17 – was *Acacia constricta.* Yet it was present at only 11 of the 17 sites. This makes it impossible to describe and name this site by the most dominant species.

This diversity is in part an artifact of defining the association on a physical characteristic: a bed narrower than 5 m wide. This was the only practical way to map the arroyos using photographs. The downside is that this metric does not distinguish between rocky arroyos in the mountains and sandy arroyos, which occur in both mountains and valley bottoms, because rocky arroyos are generally steeper. For example, *Parkinsonia floridum* was exclusively in arroyos of 1-2% slope, while *P. microphyllum* was in arroyos of 2-5% slope. Likewise, brittlebush is limited to steeper, rockier gradients.

Location: On slopes of 1-5%, from the mountains and foothills to the valley bottoms, but much more common in the mountains and foothills. In the valley bottoms, the small watercourses usually join one another to become large watercourses, or they fan out into a creosote/mesquite floodplain. Where small watercourses to exist in valley bottoms, they are typically side channels of larger watercourses.

Field Identification: The width of the open channel is at less than five meters (16 feet), over at least 50% of the watercourse surveyed. If the channel was so narrow that the vegetation was simply a single strand, rather than two strands on either side of the channel, then the arroyo was not mapped separately, but considered part of the surrounding vegetation.

Photo Identification: The smallest mapped watercourses had to have a visible open channel (channels as small as one meter/3.3 feet wide were visible on the photos), while the largest had to be less than five meters (16 feet) wide. Width was measured directly off the computer screen.

Association: *Ambrosia deltoidea/Larrea tridentata-Lycium spp/Parkinsonia spp* along watercourses with beds less than 5m wide (Bursage/Creosote/Wolfberry/Palo Verde)

Classification: 154.1214R

Number of sample sites: 19

Note: The paloverdes, *Parkinsonia floridum* and *P. microphyllum*, are treated individually, and together as a species pair. The *Lycium* are lumped into a single taxon – it wasn't possible to identify species when they lacked flowers.

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Lycium spp.	19	3 (2-4)	1-4% (<1-25%)	1.4
Parkinsonia floridum/P.microphyllum	18	3 (0-5)	5-9% (0-25%)	see indiv. species below
Larrea tridentata	18	3 (0-4)	1-4% (0-25%)	1.7
Ambrosia deltoidea	15	3 (0-4)	5-9% (0-25%)	0.5
Olneya tesota	14	2 (0-4)	<1% (0-14%)	5.6
Parkinsonia microphylla	12	3 (0-5)	5-9 (0-25%)	4.6
Acacia greggii	12	3 (0-4)	1-4% (0-14%)	2.0
Acacia constricta	10	1 (0-5)	<1% (0-60%)	2.3
Hyptis emoryi	8	0 (0-4)	0 (0 to 14%)	2.0
Prosopis velutina	8	0 (0-4)	0 (0-25%)	5.0
Bebbia juncea	8	0 (0-4)	0 (0-25%)	
Encelia farinosa	9	1 (0-3)	<1% (0 to 9%)	0.9
Ziziphus obtusifolia	6	0 (0-4)	0 (no data)	
Parkinsonia floridum	6	0 (0-4)	0 (0-14%)	
Pleuraphis rigida	6	0 (0-4)	0 (0-25%)	
Hymenoclea salsola	6	0 (0-4)	0 (0-60%)	1.3
Encelia frutescens	5	0 (0-2)	0 (0 to <1%)	
Condalia globosa	5	0 (0-2)	0 (0 to <1%)	
Krameria grayi	5	0 (0-3)	0 (0 to <1%)	
Acourtia wrightii	4	0 (0-3)	0 (0 to <1%)	
Opuntia acanthocarpa	4	0 (0-2)	0 (0 to <1%)	
Ambrosia ambrosioides	4	0 (0-4)	0 (0-25%)	
Senna covesii	4	0 (0-3)	0 (0-14%)	0.6
Trixis californica	4	0 (0-3)	0 (0 to 4%)	
Calliandra eriophylla	3	0 (0-3)	0 (0 to <1%)	
Lyrocarpa coulteri	3	0 (0-3)	0 (0 to <1%)	
Sebastiana biloculare	3	0 (0-2)	0 (0 to <1%)	
Sarcostemma cynanchoides	3	0 (0-4)	0 (no data)	
Brickellia coulteri	2	0 (0-3)	0 (0-14%)	
Viguiera parishii	2	0 (0-4)	0 (no data)	

Association: *Ambrosia deltoidea/Parkinsonia microphylla/Stenocereus thurberi* (Bursage/Palo Verde/Organ Pipe Cactus)

Classification: 154.122

Warren et al. classification: Very similar to 154.1212. However, the present study used organ pipe cactus as a diagnostic species, while Warren et al. (1981) did not. (It occurs in 80% of their samples).

Brown, Lowe and Pase classification: 154.122 *Ambrosia deltoidea- Carnegia gigantea* mixed scrub association of the Paloverde-mixed cacti ("Arizona Upland") series (154.12)

NVCS alliance: *Ambrosia deltoidea* shrubland. It could also fall into the *Parkinsonia microphylla* shrubland, if the trees are dominant; however, the current NVCS description of the *Parkinsonia microphylla* shrubland does not even mention the presence of *Ambrosia deltoidea,* which is dominant or co-dominant in the association described below. Further, the NVCS *Parkinsonia microphylla* shrubland has no *Carnegia gigantea,* which is omnipresent and common in the association described below.

NVCS association: No similar association yet described within the *Ambrosia deltoidea* alliance. I suggest: *Ambrosia deltoidea/Parkinsonia microphylla/Stenocereus thurberi* shrubland.

Description: This diverse association is recognized by S*tenocereus thurberi,* the organ pipe cactus. *Ambrosia deltoidea* is dominant or co-dominant with *Parkinsonia microphylla,* and together these two species typically provide more than 20% cover. Occasional co-dominants include *Olneya tesota, Encelia farinosa, Larrea tridentata, Opuntia bigelovii,* and *Ambrosia dumosa.*

Saguaros were in every sample site. *Opuntia fulgida, O. acanthocarpa,* and *O. bigelovii* were present in at least 2/3 of the sites, and the latter was the dominant plant in one sample.

Notable is the diversity of species that are found in less than half of the sites, but may be common when present. These include *Sebastiana (=Sapium) biloculare* and *Acacia constricta* (both typically restricted to runnels), *Lycium berlandieri, Calliandra eriophylla, Jatropha cuneata, Eriogonum spp., Ephedra aspera,* and *Bouteloua barbata.*

Location: At elevations of 1510-2200 feet (460-670 meters), on slopes from 2 to 20% (the upper limit of this survey), and typically reaching its lowest elevations on south-facing slopes, presumably because it's warmer. The association is on gravels, sand, cobbles and bedrock of the Hyder-Gachado-Gunsight extremely gravelly loams (on the Locomotive Fanglomerate on the south side of the Little Ajo Mts); the Quilotosa-Rock Outcrop complex (foothills and slopes of the Little Ajo Mts.), and the Cipriano-Hyder-Rock Outcrop complex (in the basalt mountains).

All sites are well above the valley floor, giving refuge to the frost-sensitive organ pipe cactus. The lower limit of the organ pipe is often a straight line across a bajada, following an elevation contour like the shore of a beach, and nicely

illustrating the precise elevation needed to escape the occasionally freezing temperatures of the valley bottoms. The organ pipe cactus also apparently requires summer rains, because this species does not extend north of the Little Ajo Mountains (except for isolated individuals).

Organ pipe cactus are not limited (as this study is limited) to slopes less than 20%, so the association described here does not take in the whole of their range.

Field Identification: This association was mapped by hiking along the lower limit of the organ pipe cactus. Binoculars were handy for spotting distant individuals, which were included unless they were over 100 meters (330 feet) from the rest of the population. The upper bounds were usually the 20% slope limit of the study, but there were several places (mostly in the Little Ajo Mts.) where this association graded upslope into associations holding either elephant tree or jojoba in addition to organ pipe.

Photo Identification: This association could not be distinguished on photos from other upland associations with foothill palo verde and ironwood.

Association: *Ambrosia deltoidea/Parkinsonia microphylla/Stenocereus thurberi* (Bursage/Palo Verde/Organ Pipe Cactus)

Classification: 154.122

Number of sample sites: 32

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Ambrosia deltoidea	32	4 (2-5)	10-14% (<1%- 25%)	0.45
Parkinsonia microphylla	32	3 (2-4)	5-14% (1-25%)	3.6
Larrea tridentata	32	3 (2-4)	5-9% (<1%-14%)	1.2
Stenocereus thurberi	32	2 (1-3)	<1% (<1%)	
Carnegiea gigantea	32	3 (2-3)	<1% (<1%)	
Olneya tesota	30	2-3 (0-4)	1-4% (0-9%)	2.8
Opuntia acanthocarpa	30	3 (0-3)	<1% (0 to 4%)	
Opuntia fulgida	30	2 (0-3)	<1% (0 to 4%)	
Fouquieria splendens	29	3 (0-4)	<1% (no data)	
Krameria grayii	28	2 (0-4)	<1% (0-14%)	
Opuntia bigelovii	23	3 (0-4)	<1% (0-25%)	
Lycium sp.(berlandieri?)	19	1 (0-3)	<1% (0 to <1%)	
Echinocereus nicholii	19	1 (0-3)	<1% (0 to <1%)	
Encelia farinosa	18	1.5 (0-4)	<1% (0-9%)	
Krameria erecta	15	0 (0-3)	0 (0-4%)	
Sebastiana biloculare	14	0 (0-3)	0 (0 to <1%)	
Chorizanthe rigida	13	0 (0-3)	0 (0 to <1%)	
Ferrocactus emoryi	13	0 (0-2)	0 (0 to <1%)	
Ambrosia dumosa	11	0 (0-4)	0 (0-14%)	
Acacia constricta	9	0 (0-2)	0 (0 to <1%)	
Jatropha cuneata	9	0 (0-4)	0 (0-9%)	
Opuntia leptocaulis	5	0 (0-1)	0 (0 to <1%)	
Calliandra eriophylla	5	0 (0-3)	0 (0 to <1%)	
Erioneuron pulchellum	5	0 (0-3)	0 (0 to <1%)	
Echinocereus engelmannii	4	0 (0-2)	0 (0 to <1%)	
Ferrocactus cylindraceus	4	0 (0-1)	0 (0 to <1%)	
Eriogonum spp.	4	0 (0-3)	0 (0 to <1%)	
Ephedra aspera	3	0 (0-3)	0 (0 to <1%)	
Bouteloua barbata	3	0 (0-3)	0 (0 to <1%)	

Association: *Ambrosia deltoidea/Parkinsonia microphylla/Opuntia bigelovii* (Bursage/Foothill Palo Verde/Teddy Bear Cholla)

Classification: 154.124

Warren et al. classification: This association is similar to the 154.1212 of Warren et al. (1981). However, organ pipe cactus occurs in 80% of their samples, while it is entirely lacking in the association described here.

Brown, Lowe and Pase classification: Probably part of the 154.122 *Ambrosia deltoidea-Carnegia gigantea* mixed scrub association of the Paloverde-mixed cacti ("Arizona Upland") series (154.12).

NVCS alliance: Most similar to the *Ambrosia deltoidea* shrubland; however, this alliance should be a *Ambrosia deltoidea* **sparse** shrubland

NVCS association: No similar association yet described within the *Ambrosia deltoidea* shrubland alliance. I suggest: *Ambrosia deltoidea/Parkinsonia microphylla/ Opuntia bigelovii* sparse shrubland.

Description: This association is similar to 154.122, the uplands rocky pediment with organ pipe cactus – but without the organ pipe cactus, which does not range north of the Little Ajo Mountains, beyond the reach of most summer storms – in fact, beyond the reach of most rain as the land slopes down towards the Gila Valley. Many of the same species that co-occurred with the organ pipe in 154.122 do range further north, and they are encompassed in the new association, 154.124.

The diagnostic species for this association is teddy bear cholla, also known as jumping cholla (*Opuntia bigelovii).* As with the organ pipe pediment association, the *O. bigelovii* pediment association is typically dominated by *Ambrosia deltoidea* and *Parkinsonia microphylla;* however, the cover of these species is lower here than they are in company of organ pipe, probably because of the reduced rainfall. The palo verde is also, on average, 0.4 m shorter. Creosote is omnipresent and common, as is ocotillo. *Krameria grayii, Carnegiea gigantea* and *Opuntia acanothocarpa* are less abundant, but present on all sample sites.

Location: Childs Mountain and the north side of the Little Ajo Mts., at elevations of 1520-1900 feet (460-580 meters), on slopes from 2-20% (the upper limit of the study). (The similar associations, 154.122 and 154.127, occurs on the warmer south slopes). It occurs on at least six different soil complexes, derived from both intrusive and extrusive rocks, whose common characteristics are "somewhat excessively drained" gravels and sands. Unlike *Stenocereus thurberi* (organ pipe cactus), *Opuntia bigelovii* is not frost-sensitive, and it often occurs on course alluvial outwash that carries the plant far downslope into the cold night air of the valleys. In the opposite direction, upslope, this association can hold frost-sensitive species like *Sebastiana (=Sapium) biloculare* and *Jatropha cuneata.*

Field Identification: This association was mapped by hiking along the lower limit of the teddy bear cholla *(Opuntia bigelovii)*, the diagnostic species. Binoculars were useful for spotting distant individuals, which were included in the range unless they were over one hundred meters (328 feet) from the rest of the population. The upper bounds were the 20% slope limit of the study, but the teddy bear cholla, like the palo verde and bursage, range well beyond, up the steepest slopes.

Photo Identification: This association was not mapped with the photos.

Association: *Ambrosia deltoidea/Parkinsonia microphylla/Opuntia bigelovii* (Bursage/Foothill Palo Verde/Teddy Bear Cholla *)*

Classification: 154.124

Number of sample sites: 29

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Ambrosia deltoidea	28	4 (0-5)	5-9% (0-25%)	0.45
Parkinsonia microphylla	29	3 (2-4)	1-4% (<1-9%)	3.1
Opuntia bigelovii	29	3 (2-5)	1-4% (<1-14%)	0.8
Larrea tridentata	29	3 (2-4)	1-4% (<1-9%)	1.1
Carnegiea gigantea	29	2 (1-3)	<1% (<1%)	
Opuntia acanthocarpa	28	2 (0-3)	<1% (0 to <1%)	
Krameria grayii	27	3 (0-3)	<1% (0-4%)	0.5
Fouquieria splendens	25	2 (0-3)	<1% (0 to <1%)	
Encelia farinosa	21	2 (0-3)	<1% (0-4%)	0.7
Ambrosia dumosa	19	2 (0-4)	<1% (0-9%)	0.4
Olneya tesota	17	2 (0-3)	<1% (0-4%)	3.2
Jatropha cuneata	16	1-2 (0-5)	<1% (0 to 4%)	1.1
Opuntia fulgida	14	0-1 (0-3)	<1% (0 to <1%)	
Krameria erecta	11	0 (0-3)	0 (0 to <1%)	
Lycium spp(berlandieri?)	7	0 (0-2)	0 (0 to <1%)	
Sebastiana biloculare	7	0 (0-2)	0 (0 to <1%)	
Echinocereus nicholii	7	0 (0-2)	0 (0 to <1%)	
Erioneuron pulchellum	6	0 (0-3)	0 (0 to <1%)	
Eriogonum spp.	6	0 (0-3)	0 (0 to <1%)	
Echinocereus engelmanii	6	0 (0-3)	0 (0 to <1%)	
Ferrocactus emoryi	4	0 (0-1)	0 (0 to <1%)	
Ferrocactus cylindraceus	3	0 (0-1)	0 (0 to <1%)	
Opuntia ramosissima	3	0 (0-3)	0 (0 to <1%)	

Association: *Ambrosia spp/Larrea tridentata* with less than 10% cover of *Parkinsonia microphlla/Olneya tesota* (Bursage/Creosote with less than 10% cover of Foothill Paloverde/Ironwood) ")

Classification: 154.125

Warren et al. classification: Not present at Organ Pipe Cactus NM. It was also not on the BLM lands north of Organ Pipe Cactus NM (Malusa, 2003). Because this is generally a pediment association, it can be seen as a more arid version of Warren et al.'s 154.1212, with few paloverde and ironwood.

Brown, Lowe and Pase classification: 154.121 *Ambrosia deltoidea-Parkinsonia microphylla* mixed scrub association of the Paloverde-mixed cacti ("Arizona Upland") series (154.12)

NVCS alliance: *Ambrosia deltoidea* shrubland. It could also fall into the *Parkinsonia microphylla* shrubland, if the trees are dominant; however, the current NVCS description of the *Parkinsonia microphylla* shrubland does not even mention the presence of *Ambrosia deltoidea*, which is dominant or co-dominant in the association described below. Further, the NVCS *Parkinsonia microphylla* shrubland has no *Carnegia gigantea*, which is omnipresent and common in the association described below.

NVCS association: No similar association yet described within the *Ambrosia deltoidea* alliance. I suggest *Ambrosia deltoidea/ Larrea tridentata*/*Parkinsonia microphylla-Olneya tesota* shrubland.

Description: . *Ambrosia deltoidea* is generally the dominant shrub, with *Larrea* common and occasionally co-dominant. Foothills palo verde and/or ironwood (*Parkinsonia microphylla/Olneya tesota)* are common but scarce – they form an overstory of typically less than 5% cover. *Krameria erecta* was co-dominant at 1 of the 9 sample sites, and *Ambrosia dumosa* was co-dominant at 2 of the 9.

Conspicuous cactus include *Opuntia fulgida* and *Carnegiea gigantea* (at all 9 sample sites), and *O. acanthocarpa* (8 of 9). *Ferrocactus emoryi, Echinocereus nicholii, E. engelmennii, and O. leptocaulis* are on at least one third of the samples. The only grass that was abundant enough to be ranked "common" was *Erioneuron pulchellum.*

Location: At elevations of 1540-2000 feet (470-610 meters), on slopes of 5 to 20% (the upper limit of this study), on middle and upper bajadas (alluvial fans) that are usually much dissected by arroyos. These arroyos are too small to be mapped – they're more like creases in the hills – but they are a hallmark of this association. In some places, like the south flank of Black Mountain, there is Arizona Upland on the slopes, but a stripe of treeless creosote/bursage association along the ridgeline, where there is apparently not enough runoff.

Most of this association occurs on soils mapped as either the Gunsight-Rillito-Carrizo complex, or the Hyder-Gachado-Gunsight extremely gravelly loams. The comment element, Gunsight soils, are extremely gravelly and loamy and are

underlain by a very limy layer at a depth of 5 to 24 inches. Around 40 to 70 percent of the surface is pebbles.

On the north side of the Little Ajo Mountains, this association is found on the Quilotosa-Momoli-Carrizo complex and the Quilotosa-Rock Outcrop complex. Quilotosa soil is very shallow and with a surface that is 50 to 90 percent pebbles, cobbles, stones and boulders. It is derived mainly from granite and gneiss.

Field Identification: The dominant or co-dominant is usually *Ambrosia deltoidea* or *Parkinsonia microphylla,* and occasionally *A. dumosa* or *Krameria grayii. Larrea tridentata* is not dominant. Downslope, this association grades into 154.117, a similar association, but with *Larrea* dominant, and less tree cover (<10% combined cover for palo verde and ironwood). Upslope, it grades into pediment associations holding either the frost-sensitive organ pipe cactus (*Stenocereus thurberi),* or *Opuntia bigelovii,* both of which were mapped on the ground.

Photo Identification: The lower limit was based simply on the apparent density of trees, using a cutoff of 10% combined cover for foothill palo verde and ironwood (the two are indistinguishable on the photos). As for the upper limit, it was either the 20% slope limit of the study, or the occurrence of the pediment species. The latter were not visible on the photos, and were drawn by hand, in the field.

Association: *Ambrosia spp/Larrea tridentata* with less than 10% cover of *Parkinsonia microphylla/Olneya tesota* (Bursage/Creosote with less than 5% cover of Foothill Paloverde/Ironwood)

Classification: 154.125

Number of sample sites: 7

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Ambrosia deltoidea	7	5 (3-5)	10-14% (1-25%)	0.5
Larrea tridentata	7	3 (2-3)	1-4% (<1-14%)	1.0
Parkinsonia microphylla	7	3 (2-3)	1-4% (<1-9%)	2.9
Opuntia acanthocarpa	7	3 (1-3)	1-4% (<1 to 9%)	
Krameria grayii	7	3 (2-3)	<1% (<1 to 4%)	0.5
Carnegiea gigantea	7	2 (1-3)	<1% (<1%)	
Fouquieria splendens	6	2 (0-3)	<1% (0 to <1%)	
Opuntia fulgida	5	1 (0-3)	<1% (0 to <1%)	
Encelia farinosa	3	2 (0-3)	<1% (0-9%)	0.65
Ambrosia dumosa	3	0 (0-5)	0 (0-9%)	0.5
Olneya tesota	3	0 (0-3)	0 (0-4%)	2.5
Opuntia leptocaulis	3	0 (0-3)	0 (0 to <1%)	
Opuntia bigelovii	2	0 (0-1)	0 (0 to <1%)	
Lycium berlandieri	2	0 (0-2)	0 (0 to <1%)	
Erioneuron pulchellum	2	0 (0-3)	0 (0 to <1%)	
Jatropha cuneata	1	0 (0-4)	0 (0 to 4%)	1.1
Eriogonum spp.	1	0 (0-2)	0 (0 to <1%)	
Krameria erecta	1	0 (0-3)	0 (0 to <1%)	
Echinocereus engelmanii	1	0 (0-2)	0 (0 to <1%)	
Ferrocactus emoryi	1	0 (0-1)	0 (0 to <1%)	
Ferrocactus cylindraceus	1	0 (0-1)	0 (0 to <1%)	

Association: *Ambrosia dumosa/Pleuraphis rigida/Larrea tridentata* (White Bursage/Big Galleta Grass/Creosote)

Classification: 154.126

Warren et al. classification: Not classified, but they reported *Hilaria rigida (=Pleuraphis rigida)* to be found in 4 of 12 sites in their 154.1115R (creosote/mesquite floodplain), and in 4 of their 41 sites of their 154.1112 (creosote/bursage with occasional paloverde and ironwood).

Brown, Lowe and Pase classification: Not classified. However, Turner and Brown (1982) suggest that *Larrea tridentata*/*Pleuraphis rigida* is a series of the Lower Colorado Subdivision of the Sonoran Desert.

NVCS alliance: There is a *Larrea tridentata* **shrubland** alliance currently in the database; the alliance in this study is a *Larrea tridentata* **sparse shrubland**, with the "sparse" indicating less than 25% cover. There is also a *Pleuraphis rigida* Shrub Herbaceous Alliance in the database, but with no data to back it up.

NVCS association: There is no similar association. The closest parallel is the *Ambrosia dumosa / Pleuraphis rigida* Dwarf-shrubland association from sand dunes; however, this association lacks *Larrea tridentata* as the co-dominant/dominant species.

Description: On low and sandy swales, *Larrea tridentata* is co-dominant to dominant, while *Pleuraphis rigida* is common (rarely, it may be locally dominant). *Ambrosia dumosa* is at 20 of 27 sites, with a median prominence of common. *Krameria grayii* is at only 14 sites, but common at 9 of those 14. Because it's missing from so many sample sites, its median prominence is "rare. These two species, *Ambrosia dumosa* and *Krameria grayii*, make up 15-20% of pronghorn scat during dry summers and dry winters (Hervert et al., 2000).

Perennials present at one-third or less of the sites yet occasionally deemed "common" include ocotillo (*Fouquieria splendens)*, *Prosopis spp.,* and a remarkable 6 species of *Opuntia.* One of these, *O. kunzei,* was present at only four sites, yet ranked a codominant at one these sites, in the O'Neil Hills. .

Location: On slopes of 1 to 10%. The steeper slopes are not hillsides, but instead rolling swales. They can be sandy or of much finer grain – almost like loess, and very likely windblown. This association is also on fan terraces above the Growler Wash, and in places that would appear, at first glance, to be creosote flats. They *are* creosote flats, but they surround islands of *Pleuraphis rigida*. Along Daniel's Arroyo, for example, there are at least three creosote flats, each over a mile across, that are in fact at least 25% *Larrea trindentata/Pleuraphis rigida* – you just can't see it from the edge.

The soil map of the BLM lands to the east show this association on the Denure-Coolidge complex, whose top 2-4 inches is typically a gravelly to very gravelly, sandy to very-fine sandy loam. This association also occurs on the Dateland-Cuerda complex, soils more typical of flood plains, and characterized by upper surfaces (up to 35 inches deep) of fine or very fine sandy loams, or stratified

loams. And, finally, it also occurs on the Gunsight-Rillito-Carrizo complex, characterized by gravelly to very gravelly loams.

Field Identification: While mapping the BLM lands to the east (Malusa, 2003), my sole requirement for this association was that *Pleuraphis rigida* was common, with a cover of at least 5%. For the refuge, where there's less rain and fewer plants, the requirement is a cover of 1-4%. Keep in mind, also, that in this association creosote must be dominant or co-dominant. If *Ambrosia dumosa* and/or *Pleuraphis rigida* are dominant, it is the sand dune association described below (154.126). Occasionally, it is common in shallow watercourses, with *Lycium* and other arroyo species; these occurrences of *Pleuraphis* were not included in this association, but included in one of the arroyo associations. Likewise, when there are dense patches of *Pleuraphis* in vague channels, these were included in the floodplain association.

Photo Identification: The wind-blown sands that are favored by *Pleuraphis rigida* are visible as a "smear" on the photographs. On the satellite image marketed by "Above and Beyond" (dohrenwedn@rkymtnhi.com) and titled "Organ Pipe Cactus National Monument", the creosote/big galleta association is pink, probably because the sands are often pink. Otherwise, the pattern of vegetation is similar to a creosote flat, with regular dispersion between the plants, particularly when the vegetation is almost entirely creosote and big galleta grass.

Association: *Ambrosia dumosa*/*Pleuraphis rigida*/*Larrea tridentata* (White Bursage/Big Galleta Grass/Creosote)

Classification: 154.126

Number of sample sites: 10

Taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Ambrosia dumosa	10	4 (3-5)	1-4% (1-14%)	0.5
Pleuraphis rigida	10	4 (2-5)	1-4% (<1 to 9 %)	0.8
Larrea tridentata	10	3 (2-4)	1-4% (<1 to 9 %)	1.3
Krameria grayii	3	0 (0-3)	0 (0 to <1%)	
Fouquieria splendens	2	0 (0-2)	0 (0 to <1%)	
Ferrocactus wislizeni	1	0 (0-1)	0 (0 to <1%)	
Psorothamnus emoryi.	3	0 (0-3)	0 (0 to <1%)	0.7
Opuntia echinocarpa	4	0 (0-2)	0 (0 to <1%)	
Opuntia acanthocarpa	1	0 (0-1)	0 (0 to <1%)	
Hesperocallis undulata	3	0 (0-2)	0 (0 to <1%)	
Ephedra trifurca	5	0-1 (0-3)	0 (0 – 4%)	1.0
Ambrosia deltoidea	1	0 (0-3)	0 (0 to <1%)	

Association: *Ambrosia deltoidea/Parkinsonia microphylla/Bursera microphylla* (Bursage/Foothill Palo Verde/Elephant Tree)

Classification: 154.127

Warren et al. classification: 154.1271

Brown, Lowe and Pase classification: The association as described here is most similar to the Paloverde-mixed cacti ("Arizona Upland") series (154.12), but the presence of the very frost-sensitive *Bursera microphylla* gives it an important element of and the Copal-Torote ("Central Gulf Coast") series (154.14). Turner and Brown (1982) apparently rename the same Central Gulf series as the "Torchwood-Cardon series," which they describe as "dominated by small trees of torchwood (*Bursera hindsiana, B. microphylla)* and palo verde (*Cercidium (=Parkinsonia) microphylla),* large shrubs (*Fouquieria splendens*), and the truly tall columnar Cardon (*Pachycereus pringlei).*"

NVCS alliance: *Ambrosia deltoidea* Shrubland

NVCS association: No similar association yet described within the *Ambrosia deltoidea* alliance. I suggest that the association as described here be mapped as part of the *Ambrosia deltoidea/Parkinsonia microphylla/Stenocereus thurberi* shrubland (see 154.122 above). Further west, in the Cabeza Prieta NWR, *Bursera microphylla* becomes a far more common species, and probably justifies a unique association.

Description: This association is the most frost-sensitive in the study. It is defined by the presence of elephant tree, *Bursera microphylla*, which is uncommon or rare (fewer than five/acre). The frost-sensitive jumping bean (*Sebastiana(=Sapium) biloculare)* and limber bush (*Jatropha cuneata)* are also present.

Otherwise, it much resembles the organ-pipe pediment association, and in fact organ pipe is common at all three sample sites. Triangle-leaf bursage, foothill paloverde, and teddy bear cholla (*Ambrosia deltoidea, Parkinsonia microphylla* and *Opuntia bigelovii*) are typically co-dominants. *Encelia farinosa, Olneya tesota, Fouquieria splendens, Krameria grayii* and *Larrea tridentata* are common. Saguaro and *Opuntia acanthocarpa* are at every site.

Location: Occurs in two locales, on slopes of 10-20% (the upper limit of the study): (1) On granitoid rocks near Scarface Mountain, there are about 5 acres (2 hectares) at elevations of 1650-1700 feet (500-520 meters); and (2) in the Little Ajo Mountains, about 35 acres (14 hectares) at elevations of 2000 to 2300 feet (610-700 meters), in one large population and two smaller populations ¼ to ½ mile east. The latter small populations were not visited, but inferred, based on their location and substrate, gneiss, which is very limited in the study area, at least on slopes less than 20%. Such rocks, and this association, continue up to and beyond the slope limit of the study.

The larger population in the Little Ajo Mountains also occurs on Hyder-Gachado-Gunsight extremely gravelly sandy loams. This is worth mentioning only because I formerly believed that elephant tree exclusively occurred on intrusive rocks. But the Hyder and Gachado soils are derived from extrusive rocks, while the

Gunsight are of "mixed" origin. The sample site appeared to be a mix of rhyolite/andesite and gneiss.

Field Identification: This association was defined by the presence of elephant trees. There were several at every sample site.

Photo Identification: The photos helped find areas of light-colored, granite/gneiss that were on south-facing slopes well above the valley freezes.

Association: *Ambrosia deltoidea/Parkinsonia microphylla/Bursera microphylla* (Bursage/Foothill Palo Verde/Elephant Tree)

Classification: 154.127

Number of sample sites: 4

taxon	sites	median prominence(range)	median cover (range)
Parkinsonia microphylla	4	4 (3-4)	5-9% (1-25%)
Ambrosia deltoidea	4	3-4 (2-4)	1-9% (1-14%)
Encelia farinosa	4	3 (2-4)	1-4% (<1-9%)
Larrea tridentata	4	3 (1-4)	1-4% (no data)
Stenocereus thurberi	4	3 (2-3)	<1% (<1%)
Fouquieria splendens	4	3 (2-3)	<1% (<1%)
Olneya tesota	3	2-3 (0-3)	<1-4% (0-9%)
Sapium biloculare	4	2 (1-4)	<1% (<1%)
Bursera microphylla	4	1-2 (1-4)	<1% (0-4%)
Opuntia bigelovii	3	3-4 (0-4)	1-4% (1-9%)
Carnegiea gigantea	3	2 (2-3)	<1% (0 to <1%)
Krameria grayii	3	3 (0-3)	<1% (no data)
Opuntia acanthocarpa	3	3 (2-3)	<1% (0 to <1%)
Jatropha cuneata	3	2-3 (0-4)	<1% (0-4%)
Trixis californica	3	1-2 (0-2)	<1% (0 to <1%)
Opuntia fulgida	2	0-2 (0-2)	<1% (0 to <1%)
Ferrocactus emoryi	2	0-1 (0-2)	<1% (0 to <1%)
Lycium berlandieri	1	0 (0-2)	0 (0 to <1%)
Echinocereus engelmannii	1	0 (0-2)	0 (0 to <1%)
Ephedra aspera	1	0 (0-1)	0 (0 to <1%)
Bouteloua rothrockii	1	0 (0-2)	0 (0 to <1%)

Association: *Prosopis velutina* bosque (Mesquite woodland)

Classification: 154.180 – Despite this "new" number, it describes an association similar to Warren et al.'s 124.711R. It is not clear whether mesquite bosques should be classified under Deciduous Forest, as did Warren et al. (1981); or Riparian and Oasis Forests, as did Brown, Lowe and Pase (1979). The new number, 154,180, would do neither, and retain the bosque in the Sonoran Desert Scrubland (154.1), but not as Lower Colorado series (154.11, creosote/white bursage), nor the Arizona Upland series (154.12, foothill paloverde/mixed cacti). Specifically, 154.18 is a Sonoran Desert *Prosopis (glandulosa, velutina)* scrubland series; 154.180 is an association with no watercourse (channel). Within the NVCS system, this scrubland (characterised by >25% cover of trees over 5m) would be considered a woodland. (See below)

See below for added confusion

Warren et al. classification: 124.711R, which are "open stands of trees 15 to 20 feet tall (4.6 to 6.1 meters), forming continuous corridors along large intermittent drainages." Assuming they were following Brown, Lowe and Pase, this would be a new association and series, 124.71, Sonoran Deciduous Forest; under the Tropical-Subtropical Forests and Woodlands (124).

Brown, Lowe and Pase classification: In contrast to Warren et al., BLP called bosques the Mesquite Series (224.52) of the Sonoran Riparian and Oasis Forests (224.5). See Figure 182 in Turner and Brown (1982) for an illustration of a bosque.

NVCS alliance: *Prosopis (glandulosa var. torreyana, velutina)* Woodland

NVCS association: *Prosopis (glandulosa var. torreyana, velutina)* Woodland

Description: "Bosque" is used for lack of a better term, because the mesquite woodlands on the BLM lands are usually not "open stands of trees," but more often a fierce tangle of mesquite that can form an impenetrable thicket. Cover often exceeds 80%, with the open patches attributable to downed trees; when the rains are good, such patches are crowded with mallows. The trees are up to 10 meters (33 feet), with the tallest towards the center of the patch.

However, the term "bosque" overstates this association to those who are familiar with more humid climes. The bosques here are perhaps better described as "floodplains with a reliable subsurface water source." They also appear relatively transient, associated with (a) heavy rains that allow establishment of mesquite; and (b) some topographic feature that retains the water, a feature that may not persist. This is in contrast to typical bosques, which are perched on floodplain above a major arroyo/subterranean water source.

Location: Mesquite woodlands are, within the BLM lands, associated with water diversions, some intentional (cattle tanks) and some not (the north boundary road of Organ Pipe Cactus NM creates a small woodland in one locale, by blocking sheet flow.) With cattle tanks there is typically a ring of dense mesquite, along with a stringer of similar vegetation along the earthen berms used to divert the

water. The largest piece of such habitat is a kilometer-long strip in the Cuerda de Lena, between Eberling Tank and Little Eberling Tank.

Field Identification: Besides the nearly continuous cover of large mesquite, there is no clear channel. (If there is a channel, it is classified as an arroyo, not a woodland.) This association can grade into arroyos and creosote/mesquite floodplain; the former is recognized by its distinct channel, the latter by less than 60% cover of mesquite, and no channel.

Photo Identification: The photos were taken during the month of June, before the summer rains, and the trees in these woodlands were among the only vegetation to appear red in the near-infrared image. The crowns of larger trees are visible, and mapped where it appears they form a continuous canopy.

Number of sample sites: One, from the San Crisobal Valley, on the border of the refuge and the Goldwater Range.

taxon	Prominence (n=1)	Cover	Height(meters)
Prosopis velutina	5	40-60%	6
Parkinsonia floridum	3	10-14%	6
Lycium spp.	3	1-4%	2
Larrea tridentata	3	1-4%	2
Acacia greggii	2	<1%	
Ambrosia dumosa	2	<1%	

Association: *Prosopis velutina/Parkinsonia floridum/Acacia greggii/Lycium* along watercourses with beds greater than five meters wide (Mesquite/blue palo verde/catclaw acacia/wolfberry)

Classification: 154.181 (see below). Although this is essentially the same association as Warren et al.'s 154.1215R, it is assigned a new number here because it is floristically not part of the Lower Colorado series (154.11, creosote/white bursage), nor the Arizona Upland series (154.12, foothill paloverde/mixed cacti). Specifically, 154.18 is the Sonoran Desert *Prosopis (glandulosa, velutina)* scrubland series; 154.181 is an association with a watercourse over 5m wide, with *Parkinsonia floridum/Acacia greggii/Lycium* common or co-dominant. Within the NVCS system, this scrubland (characterised by >25% cover of trees over 5m) would be considered a woodland.

Warren et al. classification: 154.1215R.

Brown, Lowe and Pase classification: Somewhat similar to 154.115, which is called the "*Cercidium (=Parkinsonia) floridum-Olneya tesota-Dalea spinosa (=Psorothamnus spinosus*) association". However, as described in Turner and Brown (1982), this association is characterized by the "poor representation or absence" of *Prosopis*, which, in contrast, is a co-dominant tree in the association described below.

NVCS alliance: Currently not described. Within the NVCS hierarchy, there is a formation (a physiognomic level, *above* alliance) classified as "Intermittently flooded extremely xeromorphic deciduous subdesert *shrubland*." However, the association described here is not a shrubland; instead, it is composed primarily of trees over 5 m tall, and with over 25% cover. Hence, this formation is an "Intermittently flooded extremely xeromorphic deciduous subdesert *woodland*."

Among described *alliances* in the NVCS, there is a *Parkinsonia floridum -Olneya tesota* Woodland; this may be congruent with this association, but there is little data to support it. The NVCS also describes two *Prosopis (glandulosa, velutina)* Alliances -- a *shrubland* and a *woodland* -- with the following caveat: "Classification of *Prosopis velutina*-dominated stands needs clarification. Because *Prosopis velutina* can have both shrub and tree growth forms, there may be confusion classifying a given stand. For example, what characteristic separates a *Prosopis velutina* arroyo riparian shrubland from a *Prosopis velutina* 'bosque' or riparian woodland. Some arroyo riparian stands in Arizona are similar to stands in the *Baccharis sarothroides*-, *Acacia greggii*- and *Parkinsonia* spp.-dominated alliances as far a species composition and separated mainly by dominance."

NVCS association: Not described. I suggest "*Prosopis(glandulosa,velutina)/Parkinsonia floridum* intermittently flooded woodland." This differs from a bosque (woodland), which lacks a watercourse running through it, and usually is not flooded; it instead borders a watercourse.

Description: Along watercourses (also known as washes or arroyos) with beds greater than five meters (16 feet) wide, mesquite (*Prosopis)* and blue palo verde

(*Parkinsonia floridum)* are always present, and typically common. With mean heights of 6.6m/22ft and 7.2m/24ft, respectively, they can provide welcome shade.

Catclaw acacia (*Acacia greggii)* and wolfberry (the various species of *Lycium* are lumped into a single category) were present at 17 of 18 sites, typically common, but with highly variable cover.

Large watercourses are, like small watercourses, very diverse. Excluding the four most common taxa (above), there are nine species whose prominences at various sites range from absent to co-dominant. *Baccharis sarothroides,* for example, is present in only 7 of the 18 sites, but is co-dominant at three of those sites. This results in a very different physiognomy – an arroyo bordered by tall shrubs rather than a corridor of trees. This sort of shift – from trees to shrubs – appears to be caused by wandering watercourse that has left its former channel. This, is turn, appears more likely as the gradient decrease and it is easier for the arroyo to change course during floods.

Yet another reason for the high diversity is the inclusion of large watercourses in mountain canyons and foothills. These can be rocky and hold "upslope" species like *Calliandra eriophylla* (fairy duster) and *Encelia farinosa* (brittle bush), which were never seen in the valley bottoms.

Location: Slopes of 1-3%, predominantly in valley bottoms, but occasionally forming in large canyons and foothills.

Field Identification: The width of the open channel is at least five meters (16 feet), over at least 50% of the watercourse surveyed. If the channel was braided so that the islands between were continuous mesquite/blue palo verde habitat, then the widths of the two strands of the braid were summed. If the islands between were a different association, then the strands were mapped separately, which sometimes resulted in a large arroyo turning into two or more small washes, then rejoining as a large wash.

Creosote/mesquite floodplain often bordered large watercourses. If the proportion of mesquite or palo verde trees exceeded that of creosote or bursage, the association was mapped as part of the watercourse.

Photo Identification: The width of the open channel was measured directly from the photos. Mapping was simple where large watercourses are bordered by creosote or creosote/bursage associations, and more difficult where bordered by floodplain. The line between floodplain and watercourse was drawn where it appeared the dense wolfberry at the outer fringe of the watercourse graded into sparser creosote or bursage, typically with scattered small mesquite (<3m).

Association: *Prosopis velutina/Parkinsonia floridum/Acacia greggii/Lycium* along watercourses with beds greater than five meters (16 feet) wide (Mesquite/blue palo verde/catclaw acacia/wolfberry*)*

Classification: 154.181

Number of sample sites: 23

Note: The *Lycium* are lumped into a single taxon – it wasn't possible to identify species when they lacked flowers.

taxon	sites	median prominence(range)	median cover (range)	mean height(in meters)
Lycium spp.	23	3 (1-5)	1-4% (<1%-25%)	1.4
Parkinsonia floridum	19	3 (0-4)	5-9% (<1-25%)	6.7
Acacia greggii	19	3 (0-4)	10-14% (0-40%)	2.3
Larrea tridentata	19	2 (0-3)	<1% (0-9%)	1.9
Prosopis spp.	18	3 (0-5)	5-9% (<1-40%)	5.9
Ambrosia ambrosioides	14	3 (0-4)	5-9% (0-25%)	1.75
Ambrosia deltoidea	15	2 (0-4)	<1% (0-14%)	
Hymenoclea salsola	14	3 (0-5)	1-4% (0-80%)	1.2
Bebbia juncea	13	2 (0-5)	<1% (0-14%)	0.8
Olneya tesota	12	1 (0-4)	<1% (0 to 14%)	4.9
Parkinsonia microphylla	11	0 (0-4)	0 (0-40%)	3.6
Encelia farinosa	10	0 (0-3)	0 (0 to <1%)	
Condalia globosa	8	0 (0-3)	0 (no data)	
Acacia constricta	8	0 (0-4)	0 (0-25%)	
Ziziphus obtusifolia	7	0 (0-3)	0 (no data)	
Baccharis sarothroides	6	0 (0-4)	0 (0-40%)	2.2
Sebastiana biloculare	6	0 (0-4)	0 (no data)	
Calliandra eriophylla	5	0 (0-4)	0 (0 to 14%)	
Clematis drummondii	5	0 (0-3)	0 (no data)	
Chilopsis linearis	4	0 (0-4)	0 (0 to 40%)	5.0
Hyptis emoryi	4	0 (0-3)	0 (0 to <1%)	
Acourtia wrightii	4	0 (0-2)	0 (0 to <1%)	
Nicotiana obtusifolia	4	0 (0-3)	0 (0 to <1%)	
Brickellia coulteri	3	0 (0-3)	0 (0 to <1%)	
Atriplex canescens	3	0 (0-1)	0 (0 to <1%)	
Encelia frutescens	3	0 (0-2)	0 (0 to <1%)	
Ambrosia confertiflora	3	0 (0-4)	0 (no data)	
Celtis pallida	3	0 (0-3)	0 (0 to <1%)	
Trixis californica	3	0 (0-2)	0 (0 to <1%)	
Sarcostemma cynanchoides	2	0 (0-3)	0 (no data)	
Hymenoclea monogyra	2	0 (0-4)	0 (0 to 40%)	2.0
Baccharis brachyphylla	2	0 (0-3)	0 (0 to 14%)	

Acknowledgements

Four years later, I'm still happy that Tim Tibbitts of Organ Pipe Cactus NM made this project happen, and that Bill Halvorson of the USGS kept it going. Sue Rutman and Karen Reichhardt provided extra brains and money. In the field, I was lucky enough to have the company and help of Pete Sundt and Peter Friederici and Ray Turner (sorry about the hurricane, Ray). The folk at Cabeza Prieta NWR frequently made my day -- friendly talk with Vergial Harp and a long walk with Curt McCasland. And Arizona Game and Fish took me up in their pronghorn plane to see the place from above – thanks to John Hervert and Bob Henry.

Back at the UA herbarium, the true botonists -- Phil Jenkins, Richard Felger and Michael Chamberland -- would collectively grimace as I pulled a squashed plant out of a plastic bag… but soon came to my aid and identified evey stick and stigma. My work was also made easier with the publication of Richard's marvelous "Flora of the Gran Desierto and Northwestern Mexico." (UA Press, Tucson, AZ., 2000).

My stack of field notes became a database with the swift hands of Debbie Angel. Later, in the ART lab at the University of Arizona, I would still be turning off the computer by pulling the plug out of the wall if not for the patience and guidance of Mickey Reed, Craig Wissler, Andy Honaman, Patty Guertin, and Patrick Barabe.

There would be no map if not for my wife, Sonya Norman, who let me vanish into the great big desert.

Thanks to all.

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