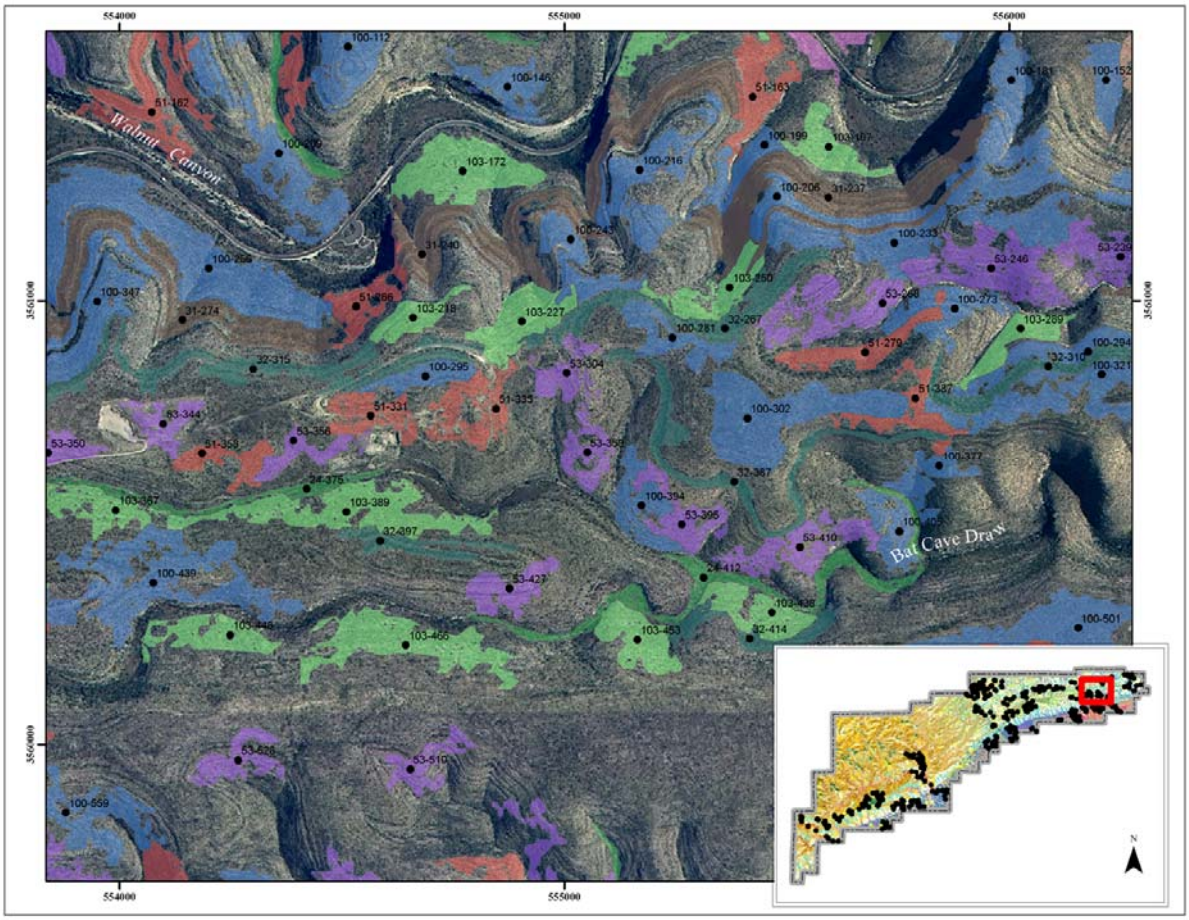
Carlsbad Caverns National Park Vegetation Map
Accuracy Assessment



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Carlsbad Caverns National Park Vegetation Map Accuracy Assessment[1]

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Summary

An accuracy assessment was conducted of the Carlsbad Caverns National Park (CAVE) Vegetation Map completed in 2003 under the auspices of the park. Following the standards and procedures of the National Mapping Program, 328 validation plots were collected in summer of 2006 distributed proportionally across map units by area. Map units were evaluated for producers' and users' errors according to the original hierarchical organization of the map legend with an upper tier (Level 1) representing the formation level of the National Vegetation Classification System (NVCS) and lowed tier (Level 3) of map units defined by NVCS alliances, plant associations, and phases. An additional middle tier was added (Level 2) to reflect the alliance and plant associations only and the grouping of units with low sample numbers. Overall accuracy at Level 1 was 91.1% (Kappa = 89.3%) and 80.5% (Kappa 78.6%) at Level 2. All individual map units in Level 1 met the minimum standard of 80%, while 15 of 19 met it at Level 2. Of those that did not, most errors were associated with closely related units. Level 3 accuracy declined an additional 6% to 74.4% (Kappa = 73.0%) when shrub phases of grassland units were considered. Specific Level 3 map units are of use, but they should be used with the knowledge that higher resolution (finer that 1:24000) site specific mapping may be required. We concluded that both Level 1 and Level 2 map units meet accuracy requirements and are sufficient for most natural resource planning and management applications.

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Introduction

In 2003, a vegetation map of Carlsbad Caverns National Park (CAVE) was completed under the auspices of the park (Muldavin et al. 2003; Appendix A). At that time, only limited accuracy assessment was completed that took advantage of an available third-party dataset of 30 NPS fire monitoring plots from the grasslands. While this small sample had an 80% users' accuracy, it was not sufficient to gauge the overall accuracy of the map following the standards of the National Mapping Program (see http://biology usgs.gov/npsveg/standards.html). Accordingly, in summer of 2006 a new field campaign was conducted through the Chihuahuan Desert Network (CHDN) Inventory and Monitoring Program, and 328 validation plots were collected across the entire spectrum of map units within the park. We report the results here and make recommendations on the use of the map in the context of users' and producers' errors (commission and omission errors, respectively) detected among the map units.

Background

The CAVE Vegetation Classification and Vegetation Map

The accuracy assessment was conducted within the boundaries of Carlsbad Caverns National Park located in southeastern New Mexico near the border with Texas (Figure 1). Detailed information on the landscape, geology, and vegetation is provided in Muldavin et al. (2003). The park is situated on a unique limestone formation derived from ancient (Permian) coral reefs deposits that give rise to diverse and unique vegetation communities. As part of the mapping project, a vegetation classification of 85 plant associations among 35 alliances was developed that range from Madrean ponderosa pine (*Pinus ponderosa*) forests at the highest elevations to low elevation Chihuahuan Desert scrub dominated by creosote bush (*Larrea tridentata*) and catclaw acacia (*Acacia neomexicana)*. The mid elevations are characterized by extensive grasslands dominated by curlyleaf muhly (*Muhlenbergia setifolia*) along with Pinchot juniper (*Juniperus pinchotii*) woodlands and scrub oak (*Quercus pungens*) shrublands (the complete classification hierarchy is provided in Appendix B).

The vegetation map was developed using a combination of automated digital processing (supervised classifications) and direct image interpretation of high-resolution satellite imagery (Landsat Thematic Mapper and IKONOS) and is raster-based (in contrast to explicit polygons). The map was composed of 34 map units derived from the vegetation classification and was designed to facilitate ecologically based natural resources management at a 1:24,000 scale with a 0.5 ha minimum map unit size. Each map unit was described in terms of primary, secondary, and inclusion plant association components. Primary component plant associations are those that are predicted to dominate a given map unit, collectively occupying at least 50% of a given delineation. Secondary components are also expected to occur but occupy less than 50%. Inclusions are those minor plant associations that may occupy up to 10% of a map unit area (the original detailed annotated legend describing component and inclusion composition of each map unit is provided in Appendix C).

Methods

Map Unit Targets and Legend Structure

Following NPS guidelines, the accuracy assessment was targeted at the plant association level and above following the National Vegetation Classification System (NVCS) (see (http://biology.usgs.gov/ npsveg/nvcs.html for the classification system). Yet, map unit legends seldom have a one-to-one correspondence to the NVCS because of the idiosyncrasies of the mapping process as driven by image quality and the degree of ground control within a given park. In the case of CAVE, the original legend was hierarchically structured into two levels with an upper level corresponding more or less to the Formation level of NVCS (e.g., Woodland, Montane Shrubland, etc,), and a lower level set of map units that were as highly refined as possible within constraints of the image analysis/interpretation potential and reference data available for a given vegetation type (Table 1, Level 1 & 3, respectively). These lower

units were variously composed of NVCS alliances and/or plant associations, and in some cases, phases of plant associations (e.g., M.U.'s 34, 101, 103, 111 and 114).

For our purposes here, there was need for a middle tier that targeted specifically the plant association level and above, and that addressed the available accuracy assessment data. Accordingly, we inserted a Level 2 in the map unit hierarchy that reflects the logical grouping of phase-based map units with their non-phase counterparts (e.g., Curlyleaf Muhly Grassland with Oak and Mountain Mahogany and Curlyleaf Muhly Grassland with Pinchot Juniper are grouped with Curlyleaf Muhly Grassland). In addition, in this middle level we merged two sets of map units to increase their joint sampling size to at least 5 samples (see sample allocation procedure below). Hence, we merged Arroyo Riparian Woodland (M.U. 14) and its 2 plots with the similar and somewhat overlapping Desert Willow Arroyo Riparian shrubland (M.U. 23) to bring the merged sample size to nine, and we merged all of the Woodland units (M.U.'s 10, 11, and 15) to bring the sample number up to five. Regardless, the accuracy assessment sampling and analysis described below evaluates all three levels represented in Table 1.

Field Data Collection

Field sampling was conducted during the summer of 2006 in two field sessions (5/23/06 – 6/11/06 and 8/22/06 – 827/06). Prior to the field work, a potential sample pool was generated using a GIS layer which included only previously un-sampled map unit delineations (raster-based pseudo-polygons made up of contiguous pixels of the same map unit). Potential polygons were selected if they occurred within one kilometer of a road or major trail and were at least one hectare in size. Polygons in the wilderness along Guadalupe Trail were excluded because road access had been closed since the development of the map, and the points made inaccessible without significant additional sampling resources. Some map units (M.U.) were excluded from the pool either because they were too small in area (<25 ha) as to be trivial for accuracy assessment (Oak-Madrone Band-cove Woodland (M.U. 12); Catclaw Mimosa Desert Shrubland (M.U. 41), Herbaceous Wetlands (M.U. 21), and Forested Wetlands (M.U. 16)), or because they represented non-vegetated or non-target human landscape elements (Agriculture/Old Field (M.U. 7), Cliff/ Rock/Barren/Arroyo Wash (M.U. 9) and Developed/Roads (M.U. 8)). A total of 2,048 potential points were identified for sampling.

Initially, the allocation of sampling effort was proportionally distributed among map units based on the area each contributed to the map (Table 1). Given our resources, we estimated that we could establish between 250 and 350 plots, and accordingly, we set both minimum and maximum targets by map unit. We stratified units such that those above 1,500 ha would receive at least 20 plots; those between 1,000 and 1,500 ha, a minimum of 15 and a maximum of 20; those between 500 and 1,000 ha, between 10 and 15; those between 100 and 500 ha, 5 to 10 plots; and those below 100 ha, three to five plots. The actual distribution of plots was dependent on the day to day logistics of the field campaign along with the uncertainty of tracking actual map units captured based on field identifications.

To support field sampling, paper maps were created at 1:12,000 scale with polygon boundaries and underlying imagery. These were used by the field crew as guidance in developing optimal sampling strategies with respect to map unit targets and logistics, and for reconnoitering in the field. The centroid location of each potential polygon was used as the initial GPS target location for sampling. In the field, crews would navigate to the centroid location and determine if the point was representative of the polygon as a whole. If not, crews were allowed to move the point to a representative area and provide a justification narrative for the move. The key was to avoid sampling small patches or fragments of plant associations not typical of the delineation. To save time, crews were also allowed to stop short of the centroid if the became clear that a closer location would be equivalent to the centroid location.

At the sample location, a validation plot was taken that included cover of the dominant species in each strata (trees, shrubs, subshrubs, grasses, and forbs), aspect (azimuth), slope (%), a brief description of the polygon landscape and composition relative to the sampling point, the GPS location (+/- 10 m precision),

and at least one representative digital photo. A total of 328 validation plots were collected distributed among map units as shown in Table 1.

Plot data was entered from the paper field sheet into the Natural Heritage New Mexico (NHNM) Plot Database (MS Access-based) and quality controlled with automated error routines and manual read-backs of the data. The digital photos were also databased and archived. Plant voucher specimens of unknowns in the field were identified and those of high quality accessioned into the University of New Mexico Herbarium.

Analysis

Initially, each validation point was classified based on dominance and indicator species into a plant association according to the CAVE vegetation classification (Appendix A). A validation point was then assigned to a map unit according to the plant association composition of the unit as reflected in the map unit descriptions provided in the annotated legend (Appendix C). In most cases, assignments were from either the primary or secondary components of the map units; inclusions accounted for only 5%.

For each level of the map legend, two accuracy measures are calculated for each map unit: a producers' and a users' accuracy (Congalton and Green 1999). Producers' accuracy reflects how well the map unit delineations represent that vegetation type on the ground and not some other vegetation type (e.g., are Pinchot juniper shrublands mapped accurately based on the field validation point locations). This provides the map maker with a measure of how well the mapping product meets specifications (also known as errors of exclusion or omission). In contrast, the users' accuracy demonstrates how well the map performs when used in the field. For example, that when a Pinchot juniper shrubland is encountered on the ground is it mapped as such and not as some other map unit. This provides the user, regardless of training, a level of confidence that what one sees on the ground is actually the element as indicated by the map (also known as errors of inclusion or commission). In addition, the 90% confidence interval was calculated by map unit for each type of error.

To quantify overall accuracy, we calculate both an overall accuracy and an estimate of Kappa (Kappa Index) for each of the three map unit levels in the legend. The overall accuracy is simply the total number of agreements between the map and reference data. The estimate of Kappa is another measure of agreement or accuracy varying from 0 to 1 (often presented as a percentage), where higher values indicate better agreement. The Kappa statistic (KHAT) is used to measure the difference between the actual agreement between the reference data and the map and the chance agreement between the reference data and a random map. KHAT indicates the extent to which the percentage correct values of an error matrix are due to "true" agreement versus "chance" agreement (Congalton and Green 1999).

The results are presented in a series of contingency tables for each level of the legend showing the producers' and users' errors by map unit with associated 90% confidence intervals, and the overall accuracy and the Kappa estimate for each level. These are also commonly referred to as "confusion" matrices.

Results

Overall accuracy was 92.1% for Level 1 map units that represented the broad formation groups of Woodland, Montane Shrubland, Grassland, Desert Shrubland, and Arroyo Riparian communities, (Table 2a). Producers' and users' error rates were similar among the map units. Errors typically occurred among the most closely related units, e.g. Desert Shrubland being confused with Grasslands, or Grasslands being confused with Desert Shrublands at lower elevations and Montane Shrublands at upper elevations. Even among the Arroyo Riparian types, which are mostly shrublands or woodlands, producers' errors were mostly confined to other shrubby upland map units. Arroyo Riparian users' errors typically reflected unmapped inclusions of narrow arroyos within upland Grassland and Montane

Shrubland polygons. While sample numbers of Woodlands were low (n = 5), the high accuracy was not surprising because these units with their tall trees were distinctive and relatively easy to interpret and delineate with the two-meter resolution IKONOS imagery (which is also why they were deemphasized in the validation sampling pool).

When moving from Level 1 to the middle Level 2, overall accuracy declined by about 10%, but it was still within the NPS minimum requirement of 80% (although Kappa dipped to 78.6%) (Table 2b). Among those units with 14 or more validation points, overall accuracy was 80.4%. As expected, most of the additional errors occurred among the most closely related map units within the same formation (bolded diagonal boxes in Table 2b). For example, in the largest map unit, Curlyleaf Muhly Grasslands (F), nearly all of the producers' and users' errors were cross-classifications with adjacent upland Grama Grasslands (G) versus the less common valley bottom Grama Terrace Grasslands (H). Similarly, the three Pinchot Juniper - Oak Shrubland (C) producers' errors were with Open Oak - Mountain Mahogany Shrubland (E) with which they share a co-dominant species. In addition, miss-classifications across formation were typically to map units that were most likely to be ecotonal with one another. For example, because the upper elevation contact of Mariola-Goldeneye Desert Shrubland (M) is most commonly with Curlyleaf Muhly Grasslands (G) that is where cross-formation errors commonly occurred. Within Arroyo Shrublands there were a few users' errors associated with Canyon-Bajada Arroyo Shrubland (P) mapping to valley bottom arroyo types (Arroyo Riparian Woodland/ Desert Willow Arroyo Riparian Shrubland (Q) or Mimosa-Acacia Arroyo Riparian Shrublands (T)).

Moving down one more step to Level 3 increased the overall error rate another 6% to 74.4% (Kappa 73.0%). The additional errors were mostly associated with phase-level differences among closely related units, particularly with respect to shrub abundance among the grassland types (Table 2c). This is reflected among the Curlyleaf Muhly Grassland map units where 101 and 103 were separated from the non-shrubby 100 by an abundance of wayleaf oak or Pinchot juniper, respectively, that could range between 10% and 25% cover. While the producers' error rate in the non-shrubby grassland (100) did not change, there was significant cross-classification of 101 and 103 with 100 suggesting that the degree of shrub cover was over estimated in the mapping process. Alternatively, shrub cover could have been underestimated in the field adding to the users' error for 100 since plot placement is critical for accurately estimating lower levels of shrub abundance such as these. Similar problems in detecting or measuring lower levels of shrub cover were evident among the Grama Grassland units (110, 111, & 112) and the Open Oak - Mountain Mahogany Shrubland (33 & 34). The disassociation of the Level 2 units of Woodland (A) and Arroyo Riparian Woodland/ Desert Willow Arroyo Riparian Shrubland (Q) into their separate units (10, 11, & 15 and 14& 20, respectively) also lowered overall accuracy a small amount, but the low within unit sample numbers made interpretation at Level 3 problematic.

Discussion

The overall accuracy of Level 1 and 2 map units was good, and for most natural resource planning and evaluations, Level 2 units will likely be sufficient and most appropriate. The attempt to further refine the units at Level 3, particularly shrubby phases, incurred additional error that may not be acceptable. The original objective in the grasslands was to define the degree of shrubbiness to support the park's fire management planning with respect to prescribed fire use in the grasslands to maintain shrub cover at levels commensurate with the natural range of variation. Because the reasons for the errors in mapping low covers of shrubs in grasslands were uncertain, we would suggest that these refined grassland units may still be valuable for fire planning, but that higher resolution sites-level evaluation/mapping will likely be required for burn prescriptions (subsequent higher precision validation sampling and evaluation may still prove the overall efficacy of the units as they are).

Conversely, the delineation of several arroyo types was also at the request of the park because of the importance of these types as wildlife habitat, yet Level 3 map unit accuracy appears acceptable although sample numbers were somewhat low. The errors were primarily associated with mapping narrow linear elements that were often small. This was a known risk during the mapping project, but one that was considered acceptable because of the importance of the habitat.

With respect to the woodland units, the validation sampling numbers were statistically inadequate, but our qualitative assessment based on the ease of image interpretation using the original ground control suggest that these units should be kept separate. The costs of errors is likely to be low compared to the costs of a sufficient validation sampling. Furthermore, these polygons tend to be small, and any direct management will likely also require higher resolution site-based mapping.

In summary, the accuracy assessment indicates that the CAVE vegetation map as mapped at Level 1 or 2 meets the basic accuracy standards for the NPS National Mapping Program (greater than 80% overall accuracy). Some individual units performed below this rate, but those that stayed above 60% were still considered viable pending further testing. In contrast, the use of some of the finer divisions of Level 3 should be used with caution with an understanding that higher resolution mapping may be required for some applications.

References

Congalton, Russell G. and Kass Green. 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices. CRC Press, Inc., Boca Raton, FL.

Muldavin, E, P. Neville, P. Arbetan, Y. Chauvin, A. Browder, and T. Neville. 2003. A vegetation map of Carlsbad Caverns National Park, New Mexico. Publication No. 03-GTR-258. Natural Heritage New Mexico, Museum of Southwestern Biology, University of New Mexico.

Tables

Table 1. Legend for the Carlsbad Caverns National Park Vegetation Map showing the original Levels 1 and 3 of the legend hierarchy and an intermediate Level 2 designed to meet the specific objectives of the accuracy assessment with respect to map unit content and sample numbers. The area (hectares and acres), the minimum sample target (Min n), the maximum sample target (Max N), the available polygon sample (Pool n), and the actual number of samples collected (Act. n) are provided for each of the original Level 3 map units. NA = not assessed.

Level 1		Level 2		Level 3		Ha	Acres	Min *n*	Max *n*	Pool *n*	Act. *n*
I	Woodlands	A	Woodlands	11	Maple - Oak Ravine Woodland	366	903	5	10	26	1
				15	Alligator Juniper — Pinyon Pine Woodland Savanna	276	682	5	10	21	2
				10	Ponderosa Pine Woodland	52	129	3	5	10	2
				12	Oak - Madrone Band Cove Woodland	21	51	NA	NA	NA	NA
II	Montane Shrublands	B	Pinchot Juniper Shrubland	32	Pinchot Juniper Shrubland	1113	2750	15	20	84	20
		C	Pinchot Juniper - Oak Shrubland	31	Pinchot Juniper - Oak Shrubland	341	844	5	10	36	14
		D	Dense Oak – Mountain Mahogany Shrubland	30	Dense Oak - Mountain Mahogany Shrubland	1619	4001	20	20	145	14
		E	Open Oak - Mountain Mahogany Shrubland	33	Moderate Oak - Mountain Mahogany Shrubland	3143	7766	20	20	263	28
				34	Sparse Oak - Mountain Mahogany Shrubland	1010	2497	15	20	112	13
III	Grasslands	F	Curlyleaf Muhly Grasslands	100	Curlyleaf Muhly Grassland	2529	6249	20	20	307	18
				101	Curlyleaf Muhly Grassland with Oak and Mountain Mahogany	1358	3356	15	20	132	23
				103	Curlyleaf Muhly Grassland with Pinchot Juniper	946	2338	10	15	137	16
		G	Grama Grasslands	110	Grama Grasslands	488	1206	5	10	46	15
				111	Grama Grasslands with Pinchot Juniper	72	178	3	5	15	8
				112	Grama Grasslands with Desert Shrubland	260	641	5	10	32	10
		H	Grama Terrace Grasslands	114	Grama Terrace Grasslands	117	290	5	10	17	8
		I	Tobosa Grasslands	120	Tobosa Grasslands	133	328	5	10	10	5

Table 1. Legend for the Carlsbad Caverns National Park Vegetation Map (continued).

Level 1		Level 2		Level 3		Ha	Acres	Min *n*	Max *n*	Pool *n*	Act. *n*
IV	Desert Shrublands	J	Viscid Acacia Desert Shrubland	40	Viscid Acacia Desert Shrubland	1011	2497	15	20	100	30
		K	Creosote Bush - Viscid Acacia Desert Shrubland	52	Creosote Bush - Viscid Acacia Desert Shrubland	440	1088	5	10	61	12
		L	Tarbush - Littleleaf Sumac Desert Shrubland	42	Tarbush - Littleleaf Sumac Desert Shrubland	101	250	5	10	13	5
		M	Mariola - Goldeneye Desert Shrubland	51	Mariola - Goldeneye Desert Shrubland	1328	3282	15	20	229	21
		N	Cactus - Ocotillo Desert Succulent Shrubland	53	Cactus - Ocotillo Desert Succulent Shrubland	857	2118	10	15	142	18
		O	Catclaw Mimosa Desert Shrubland	41	Catclaw Mimosa Desert Shrubland (not assessed)	24	60	NA	NA	NA	NA
V	Arroyo Riparian	P	Canyon - Bajada Arroyo Shrubland	24	Canyon - Bajada Arroyo Shrubland	203	503	5	10	54	10
		Q	Arroyo Riparian Woodland/ Desert Willow Arroyo Riparian Shrubland	14	Arroyo Riparian Woodland	67	164	3	5	4	2
				20	Desert Willow Arroyo Riparian Shrubland	121	300	5	10	10	5
		R	Green Sotol - Apache Plume Arroyo Riparian Shrubland	23	Green Sotol - Apache Plume Arroyo Riparian Shrubland	98	243	3	5	9	9
		S	Mixed Arroyo Riparian Shrubland	21	Mixed Arroyo Riparian Shrubland	128	315	5	10	15	9
		T	Mimosa - Acacia Arroyo Riparian Shrubland	22	Mimosa - Acacia Arroyo Riparian Shrubland	92	228	3	5	14	10
VI	Miscellaneous Map Units	U	Miscellaneous Map Units	121	Herbaceous Wetland	5	12	NA	NA	NA	NA
				16	Forested Wetland	6	14	NA	NA	NA	NA
				9	Cliff/Rock/Barren/Arroyo Wash	628	1553	NA	NA	NA	NA
				7	Agriculture/Old Field	57	142	NA	NA	NA	NA
				8	Developed/Roads	109	268	NA	NA	NA	NA

Table 2a. Level 1 accuracy assessment contingency table for the Carlsbad Caverns National Park vegetation map showing Producers' accuracy based on percent correctly validated polygons and Users' accuracy based on percent correctly mapped polygons. CI= confidence intervals around map unit percent accuracy; n = number of sampling points; % Acc. = percent accuracy. Also presented is the overall accuracy (based on the total n) and associated Kappa statistics.

Level 1		Polygons as Validated					Users' Accuracy			
		I	II	III	IV	V	*n*	%Acc.	90% CI-	90% CI+
Polygons as Mapped	I	5					5	100.0	90.0	110.0
	II		86	3		2	91	94.5	90.0	99.0
	III		1	92	8	1	102	90.2	84.9	95.5
	IV		1	6	78	1	86	90.7	85.0	96.4
	V		1	2		41	44	93.2	85.8	100.6
Producers' Accuracy	*n*	5	89	103	86	45	Σ328	**92.1**	**Overall Accuracy**	
	%Accuracy	100.0	96.6	89.3	90.7	91.1		**89.3**	**Kappa Index**	
	90% CI-	90.0	92.9	83.8	85.0	83.0		**86.3**	**Kappa 90% CI-**	
	90% CI+	110.0	100.3	94.8	96.4	99.2		**92.2**	**Kappa 90% CI+**	

Level 1 map unit key			
I	Woodlands	IV	Desert Shrublands
II	Montane Shrublands	V	Arroyo Riparian
III	Grasslands		

Table 2b. Level 2 accuracy assessment contingency table for the Carlsbad Caverns National Park vegetation map.

Level 2		Polygons as Validated																			Users' Accuracy			
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	Q	R	S	T	*n*	% Acc.	90% CI-	90% CI+
Polygon as Mapped	A	5																			5	100.0	90.0	100.0
	B		13																		13	100.0	96.2	100.0
	C		1	17												1					19	89.5	75.3	100.0
	D				12	3		1													16	75.0	54.1	95.9
	E			3	1	36	2												1		43	83.7	73.3	94.1
	F					1	44	8	1					4	1						59	74.6	64.4	84.7
	G						5	19	3							1					28	67.9	51.6	84.2
	H						1	1	4	1	3										10	40.0	9.5	70.5
	I							1		4											5	80.0	40.6	100.0
	J							1	1		25		1			1					29	86.2	73.9	98.5
	K											10		1							11	90.9	72.1	100.0
	L											1	4								5	80.0	40.6	100.0
	M					1	3					1		15							20	75.0	56.6	93.4
	N								1		2			1	17						21	81.0	64.5	97.4
	P				1											7	1			1	10	70.0	41.2	98.8
	Q						1										6				7	88.7	56.8	100.0
	R						1											9			10	90.0	69.4	100.0
	S																		8		8	100.0	93.8	100.0
	T																			9	9	100.0	94.4	100.0
Producer Accuracy	*n*	5	14	20	14	41	57	31	10	5	30	12	5	21	18	10	7	9	9	10	Σ328	**80.5**	**Overall Acc.**	
	% Acc.	100.0	92.9	85.0	85.7	87.8	77.2	61.3	40.0	80.0	83.3	83.3	80.0	71.4	94.4	70.0	85.7	100.0	88.9	90.0		**78.6**	**Kappa Index**	
	90% CI-	90.0	78.0	69.4	66.8	78.2	67.2	45.3	9.5	40.6	70.5	61.5	40.6	52.8	82.8	41.2	56.8	94.4	66.1	69.4		**74.5**	**Kappa 90% CI-**	
	90% CI+	100.0	100.0	100.0	100.0	97.4	87.2	77.3	70.5	100.0	96.2	100.0	100.0	90.0	100.0	98.8	100.0	100.0	100.0	100.0		**82.5**	**Kappa 90% CI+**	

Level 2 map unit key

L2	Level 3	Name	L2	Level 3	Name
A	10, 11, 15	Woodlands	K	52	Creosote Bush - Viscid Acacia Desert Shrubland
B	32	Pinchot Juniper Shrubland	L	42	Tarbush - Littleleaf Sumac Desert Shrubland
C	31	Pinchot Juniper - Oak Shrubland	M	51	Mariola - Goldeneye Desert Shrubland
D	30	Dense Oak - Mountain Mahogany Shrubland	N	53	Cactus - Ocotillo Desert Succulent Shrubland
E	33, 34	Open Oak - Mountain Mahogany Shrubland	P	24	Canyon - Bajada Arroyo Shrubland
F	100, 101, 103	Curlyleaf Muhly Grasslands	Q	14, 20	Arroyo Riparian Woodland/ Desert Willow Arroyo Riparian Shrubland
G	110, 111, 112	Grama Grasslands	R	23	Green Sotol - Apache Plume Arroyo Riparian Shrubland
H	114	Grama Terrace Grasslands	S	21	Mixed Arroyo Riparian Shrubland
I	120	Tobosa Grasslands	T	22	Mimosa - Acacia Arroyo Riparian Shrubland
J	40	Viscid Acacia Desert Shrubland			

Table 2c. Level 3 accuracy assessment contingency table for the Carlsbad Caverns National Park vegetation map

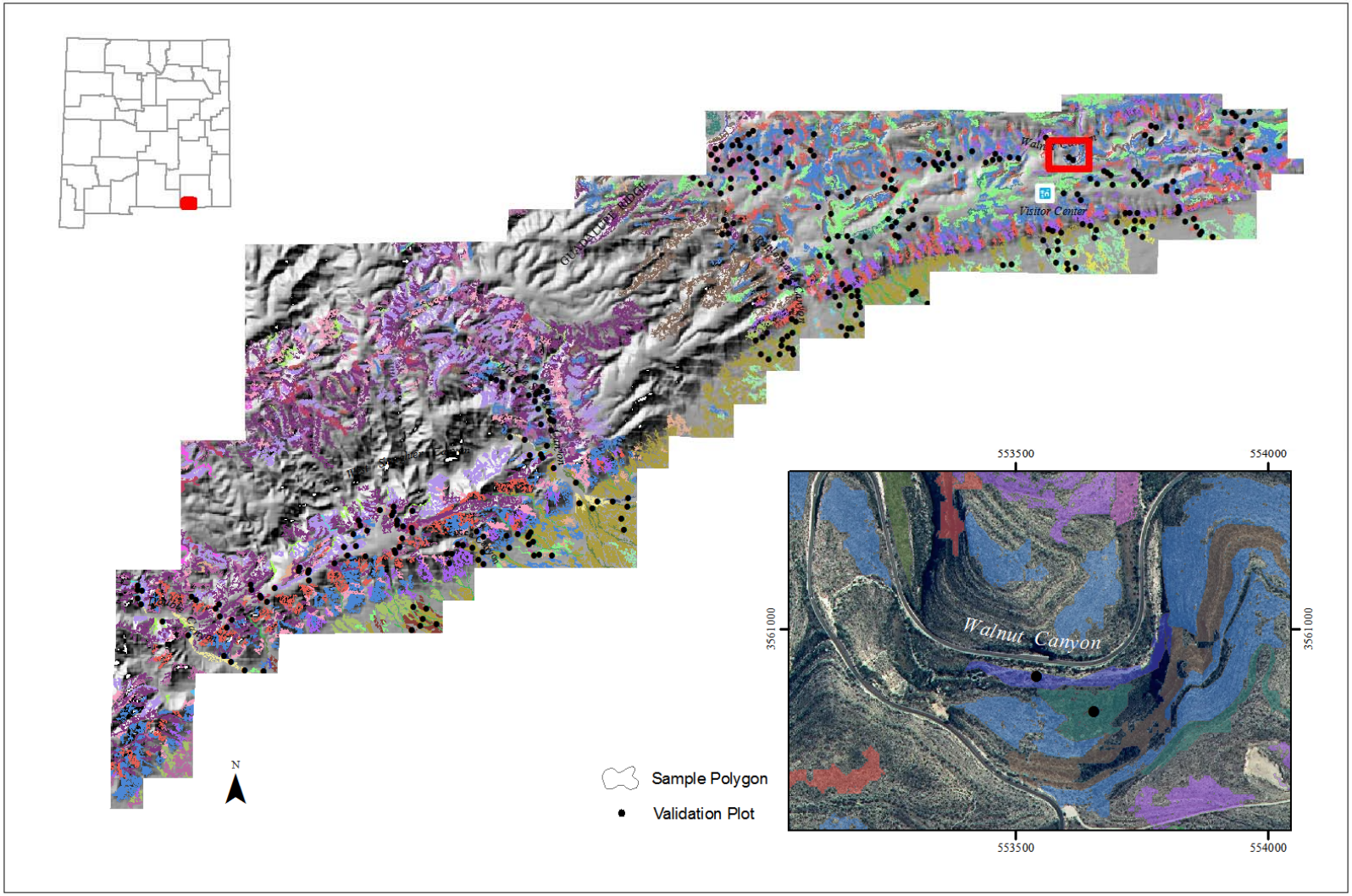
Level 3		Polygons as Validated																											Users' Accuracy			
		10	11	15	32	31	30	33	34	100	101	103	110	111	112	114	120	40	52	42	51	53	24	14	20	23	21	22	*n*	%Acc.	90% CI-	90% CI+
Polygon as Mapped	10	1																											1	100	50.0	150.0
	11		1																										1	100.0	50.0	100.0
	15		1	2																									3	66.7	5.2	100.0
	32				13																								13	100.0	96.2	100.0
	31				1	17																	1						19	89.5	75.3	100.0
	30						12	1	2				1																16	75.0	54.1	95.9
	33					2	1	26	4		1																1		35	74.3	60.7	87.9
	34					1		1	5		1																		8	62.5	28.1	96.9
	100									13	5	5	3	1		1					3	1							32	40.6	24.8	56.5
	101								1		14																		15	93.3	79.4	100.0
	103											7	1	3							1								12	58.3	30.8	85.9
	110									2		2	8	1	1	1													15	53.3	28.8	77.9
	111											1	1	2		1													5	40.0	0	86.0
	112														6	1							1						8	75.0	43.6	100.0
	114									1			1			4	1	3											10	40.0	9.5	70.5
	120														1		4												5	80.0	40.6	100.0
	40													1		1		25		1			1						29	86.2	73.9	98.5
	52																		10		1								11	90.9	72.1	100.0
	42																		1	4									5	80.0	40.6	100.0
	51								1	1	2								1		15								20	75.0	56.6	93.4
	53															1		2			1	17							21	81.0	64.5	97.4
	24						1																7		1			1	10	70.0	41.2	98.8
	14									1														2	1				4	50.0	0	100.0
	20																								3				3	100.0	83.3	100.0
	23											1														9			10	90.0	69.4	100.0
	21																										8		8	100.0	93.8	100.0
	22																											9	9	100.0	94.4	100.0
Producer accuracy	*n*	1	2	2	14	20	14	28	13	18	23	16	15	8	8	10	5	30	12	5	21	18	10	2	5	9	9	10	328	**74.4**	**Overall Acc.**	
	% Acc.	100	50.0	100	92.9	85.0	85.7	92.9	38.5	72.2	60.9	43.8	53.3	25.0	75.0	40.0	80.0	83.3	83.3	80.0	71.4	94.4	70.0	100	60.0	100	88.9	90.0		**73.0**	**Kappa Index**	
	90% CI-	50.0	0	75.0	78.0	69.4	66.8	83.1	12.4	52.1	42.0	20.2	28.8	-6.4	43.6	9.5	40.6	70.5	61.5	40.6	52.8	82.8	41.2	75.0	14.0	94.4	66.1	69.4		**68.8**	**Kappa 90 CI-**	
	90% CI+	100	100	100	100	100	100	100	64.5	92.4	79.8	67.3	77.9	56.4	100	70.5	100	96.2	100	100	90.0	100	98.8	100	100	100	100	100		**77.2**	**Kappa 90 CI+**	

Level 3 map unit key

11	Maple - Oak Ravine Woodland	30	Dense Oak - Mountain Mahogany Shrubland	53	Cactus - Ocotillo Desert Succulent Shrubland
10	Ponderosa Pine Woodland	31	Pinchot Juniper - Oak Shrubland	100	Curlyleaf Muhly Grassland
14	Arroyo Riparian Woodland	32	Pinchot Juniper Shrubland	101	Curlyleaf Muhly Grassland with Oak and Mountain
15	Alligator Juniper - Pinyon Pine Woodland Savanna	33	Moderate Oak - Mountain Mahogany Shrubland	103	Curlyleaf Muhly Grassland with Pinchot Juniper
20	Desert Willow Arroyo Riparian Shrubland	34	Sparse Oak - Mountain Mahogany Shrubland	110	Grama Grasslands
21	Mixed Arroyo Riparian Shrubland	40	Viscid Acacia Desert Shrubland	111	Grama Grasslands with Pinchot Juniper
22	Mimosa - Acacia Arroyo Riparian Shrubland	42	Tarbush - Littleleaf Sumac Desert Shrubland	112	Grama Grasslands with Desert Shrubland
23	Green Sotol - Apache Plume Arroyo Riparian Shub	51	Mariola - Goldeneye Desert Shrubland	114	Grama Terrace Grasslands
24	Canyon - Bajada Arroyo Shrubland	52	Creosote Bush - Viscid Acacia Desert Shrubland	120	Tobosa Grasslands

Figures

Figure 1. Study area for the Carlsbad Caverns National Park Vegetation Map Accuracy Assessment. Colored polygons are the available sampling pool and the dots represent actual sampling points.



Appendix A. Vegetation map of Carlsbad Caverns National Park.

Original map from Muldavin et al. (2003)

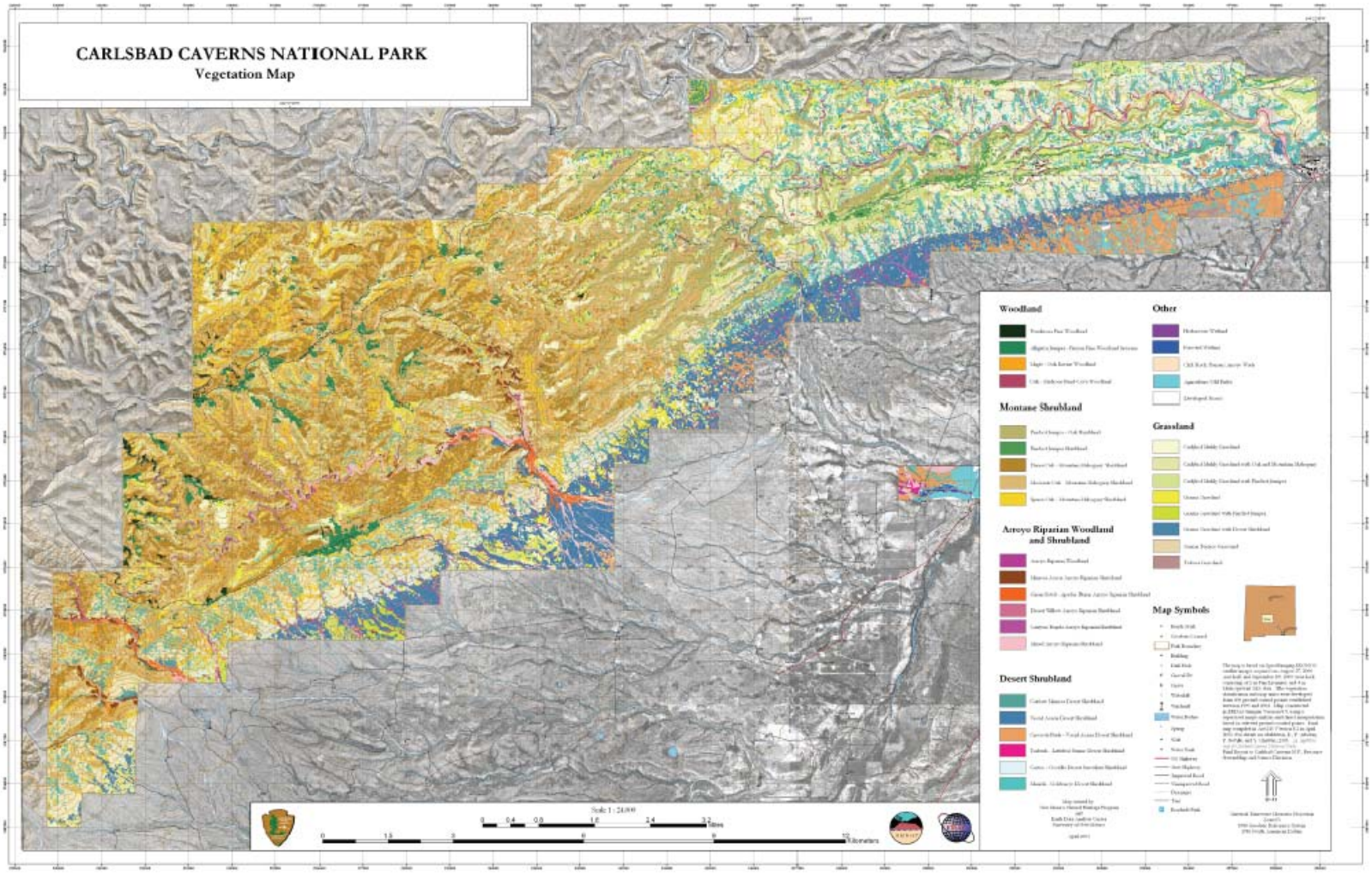


Figure 15. A reduced scale version (approximately 1:[illegible]) of the Carlsbad Caverns National Park vegetation map, 2003. See text for map and description.

Appendix B. CAVE Vegetation Classification

Original vegetation classification from Muldavin et al (2003)

Table 7. Carlsbad Caverns National Park Vegetation Classification, 2003. Vegetation units follow the New Mexico Natural Heritage Program New Mexico vegetation classification system (see Table 4). Status refers to classification confidence at the plant association level: 1 = established type, well documented (5 or more plots); 2= provisional type, limited documentation (3-4 plots); 3 = new type with minimal documentation (1-2 plots). Associations similar to those described by Bunting (1978) are marked with an "* ". S-Rank is the rarity ranks assigned for the state and G-Rank is the global rarity rank. A "?" after the rank is used for new and occasionally for provisional associations where ranking data is limited (see Methods).

Vegetation Unit	Status	S-Rank	G-Rank
I. Forest			
II. Cold Temperate Forest			
III. Madrean Montane Forest			
IV. Madrean Pine-Oak Forest			
Ponderosa Pine (*Pinus ponderosa*) Forest Alliance			
Ponderosa Pine-Chinkapin Oak/Pinyon Ricegrass Forest (*Pinus ponderosa-Quercus muehlenbergii/Piptochaetium fimbriatum* PA)	2	S1?	G2?
Ponderosa Pine/Sandpaper Oak/New Mexico Muhly Forest* (*Pinus ponderosa/Quercus pungens/Muhlenbergia pauciflora* PA)	2	S3S4	G4?
I. Woodland			
II. Cold Temperate Woodland			
III. Rocky Mountain Conifer Woodland			
IV. Rocky Mountain Pinyon-Juniper Woodland			
Pinyon Pine (Pinus edulis) Woodland Alliance			
Pinyon Pine-Sandpaper Oak Woodland* (*Pinus edulis-Quercus pungens* PA)	2	S?	G?
III. Rocky Mountain Deciduous Woodland			
IV. Rocky Mountain Broad-leaved Deciduous Woodland			
Bigtooth Maple (*Acer grandidentatum*) Woodland Alliance			
Bigtooth Maple/New Mexico Muhly Woodland (*Acer grandidentatum/Muhlenbergia pauciflora* PA)	3	S?	G?
Bigtooth Maple-Chinkapin Oak Woodland (*Acer grandidentatum-Quercus muehlenbergii* PA)	2	S1S2	G3
II. Warm Temperate Woodland			
III. Madrean Evergreen Woodland			
IV. Madrean Oak Woodland			
Gray Oak (*Quercus grisea*) Woodland Alliance			
Gray Oak/Texas Mountain Laurel Woodland (*Quercus grisea/Sophora secundiflora* PA)	2	S2	G3
Gray Oak-Bigtooth Maple Woodland (*Quercus grisea-Acer grandidentatum* PA)	2	S2	G2?
Gray Oak-Texas Madrone Woodland* (*Quercus grisea-Arbutus xalapensis* PA)	2	S2	G2?
IV. Madrean Juniper Savanna Woodland			
Alligator Juniper (*Juniperus deppeana*) Woodland Alliance			
Alligator Juniper/Sideoats Grama Woodland (*Juniperus deppeana/Bouteloua curtipendula* PA)	2	S4	G5
Alligator Juniper/Sandpaper Oak/Pine Muhly Woodland* (*Juniperus deppeana/Quercus pungens/Muhlenbergia dubia* PA)	3	S?	G?
Alligator Juniper/Sandpaper Oak/Bullgrass Woodland (*Juniperus deppeana/Quercus pungens/Muhlenbergia emersleyi* PA)	2	S4	G5
Alligator Juniper/Canyon Grape Woodland (*Juniperus deppeana/Vitis arizonica* PA)	3	S?	G?

Table 7. Carlsbad Caverns National Park Vegetation Classification, 2003 (continued).

Vegetation Unit	Status	S-Rank	G-Rank
I. Mesophytic Shrubland			
II. Cold Temperate Shrubland			
III. Madrean Montane Scrub			
IV. Broadleaved Deciduous Madrean Montane Scrub			
Shaggy Mountain Mahogany (*Cercocarpus montanus* var. *paucidentatus*) Shrubland Alliance			
Shaggy Mountain Mahogany/Little Awn Needlegrass Shrubland (*Cercocarpus montanus* var. *paucidentatus/Achnatherum lobatum* PA)	3	S3	G4
Shaggy Mountain Mahogany/Bullgrass Shrubland (*Cercocarpus montanus* var. *paucidentatus/Muhlenbergia emersleyi* PA)	1	S4	S4
Shaggy Mountain Mahogany/New Mexico Muhly Shrubland* (*Cercocarpus montanus* var. *paucidentatus/Muhlenbergia pauciflora* PA)	1	S5	G5
Shaggy Mountain Mahogany/Curlyleaf Muhly Shrubland* (*Cercocarpus montanus* var. *paucidentatus/Muhlenbergia setifolia* PA)	1	S4	G4
II. Warm Temperate Shrubland			
III. Chihuahuan Interior Chaparral			
IV. Broadleaved Chihuahuan Interior Chaparral			
Sandpaper Oak (*Quercus pungens*) Shrubland Alliance			
Sandpaper Oak/Littleawn Needlegrass Shrubland (*Quercus pungens/Achnatherum lobatum* PA)	2	S3	G4G5
Sandpaper Oak/Sideoats Grama Shrubland (*Quercus pungens/Bouteloua curtipendula* PA)	2	S3	G4G5
Sandpaper Oak/Shaggy Mountain Mahogany Shrubland* (*Quercus pungens/Cercocarpus montanus* var. *paucidentatus* PA)	2	S3	G4G5
Sandpaper Oak/New Mexico Muhly Shrubland* (*Quercus pungens/Muhlenbergia pauciflora* PA)	2	S3	G4G5
Sandpaper Oak/Curlyleaf Muhly Shrubland (*Quercus pungens/Muhlenbergia setifolia* PA)	2	S3	G4G5
IV. Needle-leaved Chihuahuan Interior Chaparral			
Pinchot Juniper (*Juniperus pinchotii*) Shrubland Alliance			
Pinchot Juniper/Sandpaper Oak/Sideoats Grama Shrubland (*Juniperus pinchotii/Quercus pungens/Bouteloua curtipendula* PA)	3	S?	G?
Pinchot Juniper/Sandpaper Oak/Hairy Grama Shrubland* (*Juniperus pinchotii/Quercus pungens/Bouteloua hirsuta* PA)	2	S?	G?
Pinchot Juniper/Skeletonleaf Goldeneye Shrubland (*Juniperus pinchotii/Viguiera stenoloba* PA)	3	S?	G?
Pinchot Juniper/Sideoats Grama Shrubland (*Juniperus pinchotii/Bouteloua curtipendula* PA)	2	S2	G?
Pinchot Juniper/Black Grama Shrubland (*Juniperus pinchotii/Bouteloua eriopoda* PA)	2	S2	G4
Pinchot Juniper/Curlyleaf Muhly Shrubland* (*Juniperus pinchotii/Muhlenbergia setifolia* PA)	2	S2	G3G4

Table 7. Carlsbad Caverns National Park Vegetation Classification, 2003 (continued).

Vegetation Unit	Status	S-Rank	G-Rank
I. Xerophytic Shrubland			
II. Warm Temperate Desert Shrubland			
III. Chihuahuan Desert Scrub			
IV. Chihuahuan Foothill-Piedmont Desert Scrub			
Viscid Acacia (*Acacia neovernicosa*) Shrubland Alliance			
Viscid Acacia/Black Grama Shrubland* (*Acacia neovernicosa/Bouteloua eriopoda* PA)	1	S4	G4
Viscid Acacia/Blue Grama Shrubland (*Acacia neovernicosa/Bouteloua gracilis* PA)	2	S4	G4
Viscid Acacia-Lechuguilla Shrubland (*Acacia neovernicosa-Agave lechuguilla* PA)	2	G5	G5
Viscid Acacia-Mariola Shrubland (*Acacia neovernicosa-Parthenium incanum* PA)	1	G5	G5
Viscid Acacia-Pricklyleaf Dogweed Shrubland (*Acacia neovernicosa-Thymophylla acerosa* PA)	3	G?	G?
Oco tillo (*Fouquieria splendens*) Shrubland Alliance			
Oco tillo-Lechuguilla Shrubland (*Fouquieria splendens-Agave lechuguilla* PA)	2	S3	G5
O cotillo-Mariola Shrubland* (*Fouquieria splendens-Parthenium incanum* PA)	1	S5	G5
Catclaw Mimosa (*Mimosa aculeaticarpa*) Shrubland Alliance			
Catclaw Mimosa/Sideoats Grama Shrubland* (*Mimosa aculeaticarpa/Bouteloua curtipendula* PA)	2	S4	G4
Mariola (*Parthenium incanum*) Dwarf Shrubland Alliance			
Mario la-Lechuguilla Desert Shrubland (*Parthenium incanum-Agave lechuguilla* PA)	3	S4?	G5?
Mariola-Skeletonlea f Goldeneye Desert Shrubland (*Parthenium incanum-Viguiera stenoloba* PA)	2	S4	G5
IV. Chihuahuan Succulent Desert Scrub			
Cactus Apple (*Opuntia engelmannii*) Shrubland Alliance			
Cactu s Apple-Lechuguilla Shrubland (*Opuntia engelmannii-Agave lechuguilla* PA)	2	S4	G5
C actus Apple-Wright Beebrush Shrubland (*Opuntia engelmannii-Aloysia wrightii* PA)	2	S4	G5
Cactu s Apple-Ocotillo Shrubland (*Opuntia engelmannii-Fouquieria splendens* PA)	2	S4	G5
IV. Chihuahuan Creosotebush Desert Scrub			
Cr eosotebush (*Larrea tridentata*) Shrubland Alliance			
Creos otebush/Sparse Undergrowth Desert Shrubland* (*Larrea tridentata/Sparse* PA)	1	S5	G5
Creos otebush-Viscid Acacia/Black Grama Desert Shrubland (*Larrea tridentata-Acacia neovernicosa/Bouteloua eriopoda* PA)	3	S?	G?
Creos otebush/Viscid Acacia/Sparse Desert Shrubland (*Larrea tridentata-Acacia neovernicosa/Sparse* PA)	2	S5	G5
Creo sotebush-Mariola Shrubland (*Larrea tridentata-Parthenium incanum* PA)	1	S5	G5

Table 7. Carlsbad Caverns National Park Vegetation Classification, 2003 (continued).

Vegetation Unit	Status	S-Rank	G-Rank
IV. Chihuahuan Basin Desert Scrub			
Tarbush (*Flourensia cernua*) Shrubland Alliance			
Tarbush/Black Grama Shrubland (*Flourensia cernua/Bouteloua eriopoda* PA)	1	S4	G4
Tarbush/Tobosagrass Desert Shrubland (*Flourensia cernua/Hilaria mutica* PA)	1	S5	G5
Littleleaf Sumac (*Rhus microphylla*) Shrubland Alliance			
Littleleaf Sumac/Sideoats Grama Shrubland* (*Rhus microphylla/Bouteloua curtipendula* PA)	2	S5	G5
Littleleaf Sumac/Blue Grama Shrubland (*Rhus microphylla/Bouteloua gracilis* PA)	1	S?	G?
Littleleaf Sumac-Texas Mountain Laurel Shrubland (*Rhus microphylla-Sophora secundiflora* PA)	1	S?	G?
IV. Chihuahuan Mesquite Desert Scrub			
Prosopis glandulosa Shrubland Alliance			
Honey Mesquite/Tobosagrass Shrubland* (*Prosopis glandulosa/Hilaria mutica* PA)	1	S5	G5
I. Grassland			
II. Cold Temperate Grassland			
III. Madrean Plains-Mesa-Foothill Grassland			
IV. Madrean Foothill Grassland			
Texas Sacahuista (*Nolina texana*) Shrub Herbaceous Alliance			
Bullgrass/Texas Sacahuista Grassland (*Muhlenbergia emersleyi/Nolina texana* PA)	3	S?	G?
Curlyleaf Muhly-Sideoats Grama/Texas Sacahuista Grassland (*Muhlenbergia setifolia-Bouteloua curtipendula/Nolina texana* PA)	3	S?	G?
Sideoats Grama/Texas Sacahuista Grassland* (*Bouteloua curtipendula/Nolina texana* PA)	2	S?	G?
II. Warm Temperate Grassland			
III. Chihuahuan Semidesert Grassland			
IV. Chihuahuan Foothill-Piedmont Desert Grassland			
Lechuguilla-Green Sotol (*Agave lechuguilla-Dasylirion leiophyllum*) Shrub Herbaceous Alliance			
Black Grama/Lechuguilla-Green Sotol Grassland (*Bouteloua eriopoda/Agave lechuguilla-Dasylirion leiophyllum* PA)	3	S?	G?
Curlyleaf Muhly/Lechuguilla Grassland (*Muhlenbergia setifolia/Agave lechuguilla* PA)	2	S1S2	G3
Curlyleaf Muhly/Lechuguilla-Green Sotol Grassland (*Muhlenbergia setifolia/Agave lechuguilla-Dasylirion leiophyllum* PA)	1	S1S2	G3
Curlyleaf Muhly/Green Sotol Grassland (*Muhlenbergia setifolia/Dasylirion leiophyllum* PA)	2	S1S2	G3
Sideoats Grama/Lechuguilla-Green Sotol Grassland (*Bouteloua curtipendula/Agave lechuguilla-Dasylirion leiophyllum* PA)	2	S2S3	G3G4
Sideoats Grama/Green Sotol Grassland (*Bouteloua curtipendula/Dasylirion leiophyllum* PA)	2	S3	G3G4
Sideoats Grama-Tanglehead/Green Sotol Grassland (*Bouteloua curtipendula-Heteropogon contortus/Dasylirion leiophyllum* PA)	2	S3	G3G4
Slim Tridens/Lechuguilla Grassland (*Tridens muticus/Agave lechuguilla* PA)	3	S?	G?

Table 7. Carlsbad Caverns National Park Vegetation Classification, 2003 (continued).

Vegetation Unit	Status	S-Rank	G-Rank
IV. Chihuahuan Foothill-Piedmont Desert Grassland (continued)			
Blue Grama (*Bouteloua gracilis*) Shrub Herbaceous Alliance			
Blue Grama/Skeletonleaf Goldeneye Grassland (*Bouteloua gracilis/Viguiera stenoloba* PA)	3	S?	G?
Blue Grama-Tobosagrass/Catclaw Mimosa Grassland (*Bouteloua gracilis-Hilaria mutica/Mimosa aculeaticarpa* PA)	3	S?	G?
Black Grama (*Bouteloua eriopoda*) Herbaceous Alliance			
Black Grama-Blue Grama Grassland* (*Bouteloua eriopoda-Bouteloua gracilis* PA)	1	S2	G2
Black Grama-Sideoats Grama Grassland (*Bouteloua eriopoda-Bouteloua curtipendula* PA)	1	S2	G2
Cu rlyleaf Muhly (*Muhlenbergia setifolia*) Herbaceous Alliance			
Cu rlyleaf Muhly-Sideoats Grama Grassland (*Muhlenbergia setifolia-Bouteloua curtipendula* PA)	1	S1S2	G3
Cu rlyleaf Muhly-Hairy Tridens Grassland (*Muhlenbergia setifolia-Erioneuron pilosum* PA)	3	S?	G?
Cu rlyleaf Muhly/Skeletonleaf Goldeneye Grassland (*Muhlenbergia setifolia/Viguiera stenoloba* PA)	3	S?	G?
Panicgrass (*Panicum hallii*) Herbaceous Alliance			
Hall's Panicgrass-Hairy Tridens Grassland (*Panicum hallii-Erioneuron pilosum* PA)	2	S?	G?
IV. Chihuahuan Lowland/Swale Semidesert Grassland			
Tobosagrass (*Hilaria mutica*) Herbaceous Alliance			
Tobosa grass-Burrograss Grassland (*Hilaria mutica-Scleropogon brevifolius* PA)	1	S5	G5
Riparian/Wetland			
I. Forested Riparian/Wetland			
II. Broadleaved Deciduous Riparian/Wetland Forest and Woodland			
III. Lowland Interior Southwest Broad-leaved Deciduous Riparian Forest and Woodland			
IV. Southwest Arroyo Riparian Woodland (intermittently flooded)			
Netleaf Hackberry (*Celtis laevigata* var. *reticulata*) Arroyo Woodland Alliance			
Netleaf Hackberry-Little Walnut Arroyo Woodland (*Celtis laevigata var. reticulata-Juglans microcarpa* PA)	3	S?	G?
Netleaf Hackberry-Littleleaf Sumac Arroyo Woodland (*Celtis laevigata var. reticulata-Rhus microphylla* PA)	3	S?	G?
Little Walnut (*Juglans microcarpa*) Arroyo Woodland Alliance			
Little Walnut/Sideoats Grama Arroyo Woodland (*Juglans microcarpa/Bouteloua curtipendula* PA)	2	S2S3	G2G3
IV. Southwest Lowland Riparian Forest and Woodland (Temporarily Flooded)			
R io Grande Cottonwood (*Populus fremontii*) Riparian Forest Alliance			
Rio Grande Cottonwood-Goodding Willow Riparian Forest (*Populus deltoides* var. *wislizenii -Salix gooddingii* PA)	1	S2	G2
Rio Grande Cottonwood-Netleaf Hackberry-Goodding Willow Riparian Forest (*Populus deltoides* var. *wislizenii -Celtis laevigata var. reticulata- Salix gooddingii* PA)	3	S?	G?
R io Grande Cottonwood-Russian Olive Riparian Forest (*Populus deltoides* var. *wislizenii -Elaeagnus angustifolia* PA)	1	SM	GM

Table 7. Carlsbad Caverns National Park Vegetation Classification, 2003 (continued).

Vegetation Unit	Status	S-Rank	G-Rank
I. Shrub Riparian/Wetland			
II. Broadleaved Deciduous Riparian/Wetland Shrubland			
III. Lowland Interior Southwest Riparian/Wetland Shrubland			
IV. Southwest Arroyo Riparian Shrubland (intermittently flooded)			
Apache Plume (*Fallugia paradoxa*) Shrubland Alliance			
Apache Plume/Wash Arroyo Shrubland (*Fallugia paradoxa*/Arroyo PA)	3	S2S3?	G?
Apache Plume/Mexican Buckeye Arroyo Shrubland (*Fallugia paradoxa*/*Ungnadia speciosa* PA)	3	S2S3?	G?
Texas Mountain Laurel (*Sophora secundiflora*) Shrubland Alliance			
Texas Mountain Laurel-Roemer Catclaw Arroyo Shrubland (*Sophora secundiflora-Acacia roemeriana* PA)	3	S2S3?	G?
Green Sotol (*Dasylirion leiophyllum*) Shrubland Alliance			
Green Sotol/Catclaw Mimosa Arroyo Shrubland (*Dasylirion leiophyllum/Mimosa aculeaticarpa* PA)	3	S?	G?
Desert Willow (*Chilopsis linearis*) Shrubland Alliance	3	S3?	G3?
Desert Willow-Texas Mountain Laurel Shrubland (*Chilopsis linearis-Sophora secundiflora* PA)			
Catclaw Acacia (*Acacia greggii*) Shrubland Alliance			
Catclaw Acacia/Bullgrass Shrubland (*Acacia greggii/Muhlenbergia emersleyi* PA)	3	S4?	G4?
Littleleaf Sumac (*Rhus microphylla*) Shrubland Alliance			
Littleleaf Sumac-Texas Mountain Laurel Shrubland (*Rhus microphylla-Sophora secundiflora* PA)	3	S?	G?
I. Emergent Herbaceous Wetland			
II. Persistent Emergent Herbaceous Wetland			
III. Lowland Western Persistent Emergent Herbaceous Wetland			
IV. Semipermanently Flooded Western Lowland Herbaceous Wetland			
Western Umbrella (*Fuirena simplex*) Herbaceous Alliance			
Western Umbrella-sedge-Sand Spikerush Herbaceous Wetland (*Fuirena simplex/Eleocharis montevidensis* PA)	3	S?	G?
Baltic Rush (*Juncus balticus*) Herbaceous Alliance			
Baltic Rush-Threesquare Bulrush (*Juncus balticus-Schoenoplectus pungens* PA)	2	S4?	G5?

Appendix C. Annotated CAVE Legend

Original annotated legend from Muldavin et al. (2003)

MAP UNIT DESCRIPTIONS

Map unit descriptions for each map unit listed in Table 8 follow. For each unit, the primary and secondary components are listed along with inclusions. Primary components are those plant associations listed in Table 7 that together comprise the majority of the unit. Secondary components are minor associations that can occupy at least 10% of the unit, but are not the dominants. Inclusions are associations that occupy less than 10% of the area. The descriptions are grouped by Woodlands, Montane Shrublands and Chaparral, Grasslands, Desert Shrublands, Arroyo Riparian Woodlands and Shrublands, and other wetland and miscellaneous types. Cover criteria by strata are provided for each map unit, along with information on distribution within the park.

Woodlands

Ponderosa Pine Woodland	**11**
Trees > 10%	
Ha: 52 **Acres:**	129
Primary Components: Ponderosa Pine/Sandpaper Oak/New Mexico Muhly	
Secondary Components: Ponderosa Pine-Chinkapin Oak/Pinyon Ricegrass	
Inclusions: Pinyon Pine-Sandpaper Oak	
Distribution: minor Madrean Montane Forest and Woodland map unit that occurs as small stands (<1 ha) on ridge top summits, north-facing slopes, and as "stringers" along canyon bottoms. Mainly in the west half of the park between 5,200 and 6,400 ft.	

Figure 2. Ponderosa Pine/Sandpaper Oak/New Mexico Muhly Woodland on the west end of Yucca Mesa ridge. Fire, plus the limited potential for reproduction, keeps most stands open. (Photo: E. Muldavin)

Alligator Juniper - Pinyon Pine Woodland Savanna	**15**
Trees >10%	
Ha: 276 **Acres:**	682
Primary Components: Alligator Juniper/Sideoats Grama Alligator Juniper/Sandpaper Oak/Pine Muhly Alligator Juniper/Sandpaper Oak/Bullgrass	
Secondary Components: Alligator Juniper/Canyon Grape	
Inclusions: Sandpaper Oak/Shaggy Mountain Mahogany Ponderosa Pine/Sandpaper Oak/New Mexico Muhly Pinyon Pine-Sandpaper Oak	
Distribution: limited Rocky Mountain Conifer Woodland map unit. Occurs as small to medium sized stands on ridge top summits, north-facing slopes, and as "stringers" along canyon bottoms. Mainly in the west half of the park between 5,000 and 6,400 ft.	

Figure 3. Alligator Juniper/Sideoats Grama Woodland Savanna on Yucca Mesa ridge at about 6,000 ft. Fires have helped maintain an open woodland savanna structure. (Photo: S. Yanoff)

Maple - Oak Ravine Woodland	**10**
Trees > 25%	
Ha: 366	**Acres: 903**
Primary Components: Bigtooth Maple/New Mexico Muhly Bigtooth Maple-Chinkapin Oak	
Secondary Components:	
Inclusions: Gray Oak-Bigtooth Maple Ponderosa Pine-Chinkapin Oak/Pinyon Ricegrass Alligator Juniper/Canyon Grape	
Distribution: limited Rocky Mountain Broad-leaved Deciduous Woodland map unit. The Bigtooth Maple/New Mexico Muhly PA occurs in small stands in north-facing ravines at elevations above 5,000 ft in the western portion of the park. The Bigtooth Maple-Chinkapin Oak PA is also found in ravines and as part of the "band-cove" woodlands at mid-elevations in the eastern portion of the park.	

Figure 4. Bigtooth Maple-Chinkapin Oak Woodland in a ravine near Hayhurst along Guadalupe Ridge (elevation 6,155 ft). (Photo: Y. Chauvin)

Oak - Madrone Band Cove Woodland	**12**
Trees > 25%	
Ha: 21 **Acres:**	51
Primary Components: Gray Oak-Texas Madrone Gray Oak-Bigtooth Maple	
Secondary Components: Bigfoot Maple-Chinkapin Oak	
Inclusions: Gray Oak/Texas Mountain Laurel Pinchot Juniper/Curlyleaf Muhly	
Distribution: minor Madrean Evergreen Woodland map unit. Small stands occur on north-facing slopes and in headslope coves where they commonly form bands along horizontal sedimentary rock strata, particularly at the contact between the Tansil and Yates formations. Mostly found at middle-elevations between 4,000 and 5,000 ft in the eastern portion of the park.	

Figure 5. A band of Gray Oak-Texas Madrone Woodland in a north-facing, mid-slope cove in lower Walnut Canyon (elevation 4,000 ft). Although limited in extent these are important wildlife habitats and corridors. (Photo: E. Muldavin)

Montane Shrublands and Chaparral

Dense Oak - Mountain Mahogany Shrubland	**30**
Tall shrubs >50%	
Ha: 1,619 **Acres:**	4,001
Primary Components: Sandpaper Oak/Shaggy Mountain Mahogany Shaggy Mountain Mahogany/Curlyleaf Muhly Sandpaper Oak/Curlyleaf Muhly Sandpaper Oak/Sideoats Grama Sandpaper Oak/New Mexico Muhly Shaggy Mountain Mahogany/New Mexico Muhly	
Secondary Components: Shaggy Mountain Mahogany/Little Awn Needlegrass Shaggy Mountain Mahogany/Bullgrass Sandpaper Oak/Littleawn Needlegrass	
Inclusions: Pinchot Juniper/Sandpaper Oak/Sideoats Grama Pinchot Juniper/Sandpaper Oak/Hairy Grama	
Distribution: major dense canopied Broadleaved Chihuahuan Interior Chaparral and Montane Shrubland map unit that occurs primarily on north-facing slopes at elevations from 5,000 to 6,400 ft. Mainly found in the western portion of the park.	

Figure 6. Sandpaper Oak/New Mexico Muhly Shrubland near Hayhurst along Guadalupe Ridge at 6,028 ft. (Photo: P. Arbetan)

Moderate Oak - Mountain Mahogany Shrubland	**33**
Tall shrubs >25% and <50%	
Ha: 3,143	**Acres:** 7,766
Primary Components: Sandpaper Oak/Curlyleaf Muhly Shaggy Mountain Mahogany/Curlyleaf Muhly Shaggy Mountain Mahogany/New Mexico Muhly Sandpaper Oak/New Mexico Muhly Sandpaper Oak/Sideoats Grama	
Secondary Components: Shaggy Mountain Mahogany/Bullgrass Sandpaper Oak/Shaggy Mountain Mahogany Sandpaper Oak/Littleawn Needlegrass Shaggy Mountain Mahogany/Little Awn Needlegrass	
Inclusions: Pinchot Juniper/Sandpaper Oak/Sideoats Grama Pinchot Juniper/Sandpaper Oak/Hairy Grama	
Distribution: major, moderately open Broadleaved Chihuahuan Interior Chaparral and Montane Shrubland that occurs primarily on ridge top summits and easterly and westerly slopes at elevations from 5,000 to 6,400 ft.	

Figure 7. Sandpaper Oak/Shaggy Mountain Mahogany Shrubland on a western ridge above Slaughter Canyon at 5,996 ft. (Photo: P. Arbetan)

Sparse Oak - Mountain Mahogany Shrubland	**34**
Tall shrubs >10% and <25%; grasses < shrubs	
Ha: 1,010	**Acres:** 2,497
Primary Components: Sandpaper Oak/New Mexico Muhly Shaggy Mountain Mahogany/New Mexico Muhly Sandpaper Oak/Sideoats Grama	
Secondary Components: Sandpaper Oak/Curlyleaf Muhly Shaggy Mountain Mahogany/Curlyleaf Muhly Shaggy Mountain Mahogany/Little Awn Needlegrass Sandpaper Oak/Littleawn Needlegrass Shaggy Mountain Mahogany/Bullgrass	
Inclusions: Pinchot Juniper/Sandpaper Oak/Sideoats Grama Pinchot Juniper/Sandpaper Oak/Hairy Grama Sandpaper Oak/Shaggy Mountain Mahogany	
Distribution: major, sparse canopied Broadleaved Chihuahuan Interior Chaparral and Montane Shrubland map unit that occurs primarily on steep, rocky, north-facing slopes at elevations from 5,000 to 6,400 ft.	

Figure 8. Sandpaper Oak/New Mexico Muhly Shrubland on a steep, rocky slope near Hayhurst at 5,714 ft along Guadalupe Ridge. (Photo: P. Arbetan)

Pinchot Juniper - Oak Shrubland	**31**
Tall shrubs >25%; oak and Pinchot Juniper co-dominants	
Ha: 1,113 **Acres:**	2,750
Primary Components: Pinchot Juniper/Sandpaper Oak/Sideoats Grama Pinchot Juniper/Sandpaper Oak/Hairy Grama	
Secondary Components: Pinchot Juniper/Sideoats Grama Pinchot Juniper/Curlyleaf Muhly	
Inclusions: Sandpaper Oak/Sideoats Grama Sandpaper Oak/New Mexico Muhly	
Distribution: major mixed Chihuahuan Interior Chaparral map unit. It occurs along the upper potion of the Loop Road extending westward along north-facing slopes between Rattlesnake Canyon and Slaughter Canyon. Elevations are typically between 4,400 and 5,500 ft.	

Figure 9. Pinchot Juniper/Sandpaper Oak/Sideoats Shrubland on a gentle upper slope along Loop Road at about 4,532 ft. (Photo: D. Odell).

Pinchot Juniper Shrubland	**32**
Tall shrubs >25%; oak <10%	
Ha: 341 **Acres:**	844
Primary Components: Pinchot Juniper/Curlyleaf Muhly Pinchot Juniper/Sideoats Grama	
Secondary Components: Pinchot Juniper/Black Grama	
Inclusions: Pinchot Juniper/Sandpaper Oak/Sideoats Grama Pinchot Juniper/Sandpaper Oak/Hairy Grama Curlyleaf Muhly/Lechuguilla-Green Sotol Sideoats grama/Lechuguilla-Green Sotol	
Distribution: limited Needle-leaved Chihuahuan Interior Chaparral map unit. It occurs along upper north-facing slopes between Rattlesnake Canyon and the mouth of Walnut Canyon. Typically occurring on ridge summits of the Tansil Formations and as bands along mid and upper slopes at elevations between 3,800 and 4,800 ft.	

Figure 10. Pinchot Juniper/Curlyleaf Muhly Shrubland on a gentle upper slope at about 4,650 ft along the Loop Road. (Photo: E. Muldavin)

Grasslands

Curlyleaf Muhly Grassland	**100**
Tall shrubs <10%	
Ha: 2,529 **Acres:**	6,249
Primary Components: Curlyleaf Muhly/Lechuguilla Curlyleaf Muhly/Lechuguilla-Green Sotol Curlyleaf Muhly/Green Sotol Curlyleaf Muhly-Sideoats Grama	
Secondary Components: Curlyleaf Muhly-Hairy Tridens	
Inclusions: Sideoats Grama/Green Sotol Sideoats Grama/Lechuguilla-Green Sotol	
Distribution: major Chihuahuan Foothill-Piedmont Desert Grassland map unit that primarily occurs on upper slopes and ridge top summits in the eastern portion of the park. Elevations range from 4,000 to 5,000 ft.	

Figure 11. Curlyleaf Muhly/Green Sotol Grassland near Rattlesnake Canyon Trailhead at 4,601 ft. (Photo: Y. Chauvin)

Curlyleaf Muhly Grassland with Oak and Mountain Mahogany	**101**
Tall Shrubs >10 and <25%; grasses dominant	
Ha: 1,358 **Acres:**	3,356
Primary Components: Curlyleaf Muhly-Sideoats Grama/Texas Sacahuista Mountain Mahogany Phase Bullgrass/Texas Sacahuista, Sandpaper Oak Phase	
Secondary Components: Sideoats Grama/Texas Sacahuista , Sandpaper Oak Phase	
Inclusions: Sandpaper Oak/Curlyleaf Muhly Shaggy Mountain Mahogany/Curlyleaf Muhly Shaggy Mountain Mahogany/New Mexico Muhly Sandpaper Oak/New Mexico Muhly Sandpaper Oak/Sideoats Grama	
Distribution: major Madrean Plains-Mesa-Foothill Grassland map unit with a shrubby component that occurs primarily on upper slopes and ridge top summits in the western portion of the park. Elevations range from 5,000 to 6,400 ft.	

Figure 12. Curlyleaf Muhly-Sideoats Grama/Texas Sacahuista, Mountain Mahogany Phase Grassland located north of Hayhurst along Guadalupe Ridge at 5,868 ft. Grasses are still dominant, and shrubs are represented by Texas sacahuista, mountain mahogany, sandpaper oak, and Pinchot juniper. (Photo: Y. Chauvin)

Curlyleaf Muhly Grassland with Pinchot Juniper	**103**
Pinchot juniper >10 and <25%; grasses dominant	
Ha: 946 **Acres:**	2,338
Primary Components: Curlyleaf Muhly/Lechuguilla, Pinchot Juniper Phase Curlyleaf Muhly/Lechuguilla-Green Sotol, Pinchot Juniper Phase	
Secondary Components: Sideoats Grama/Lechuguilla-Green Sotol, Pinchot Juniper Phase	
Inclusions: Pinchot Juniper/Curlyleaf Muhly Pinchot Juniper/Sideoats Grama	
Distribution: major Chihuahuan Foothill-Piedmont Desert Grassland map unit that occurs primarily on upper slopes and ridge top summits in the eastern portion of the park. Elevations range from 4,000 to 5,000 ft.	

Figure 13. Curlyleaf Muhly/Lechuguilla, Pinchot Juniper Phase Grassland along the Juniper Trail in the northeast portion of the park. Grasses are abundant and dominant, while Pinchot juniper is between 10% and 25% cover. (Photo: E. Muldavin)

Grama Grasslands	**110**
Tall shrubs <10%	
Ha: 488	**Acres:** 1,206
Primary Components: Sideoats Grama/Lechuguilla-Green Sotol Sideoats Grama/Green Sotol Sideoats Grama-Tanglehead/Green Sotol Black Grama-Sideoats Grama	
Secondary Components: Sideoats Grama/Texas Sacahuista Curlyleaf Muhly-Sideoats Grama/Texas Sacahuista Curlyleaf Muhly-Sideoats Grama Bullgrass/Texas Sacahuista Black Grama-Blue Grama	
Inclusions: Curlyleaf Muhly/Green Sotol Curlyleaf Muhly-Hairy Tridens Hall Panicgrass-Hairy Tridens	
Distribution: limited Chihuahuan Foothill-Piedmont Desert Grassland map unit that occurs on hill slopes and ridge top summits, and along upper piedmonts (bajadas). Elevations range from 4,000 to 6,000 ft.	

Figure 14. Sideoats Grama-Tanglehead/Green Sotol Grassland on a south-facing slope at 5,014 ft in middle Walnut Canyon. Tanglehead dominates this recently burned site. (Photo: Y. Chauvin).

Grama Grasslands with Pinchot Juniper	**111**
Pinchot juniper >10 and <25%; grasses dominant	
Ha: 72 **Acres:**	178
Primary Components: Sideoats Grama/Lechuguilla-Green Sotol, Pinchot Juniper Phase Sideoats Grama/Green Sotol, Pinchot Juniper Phase Sideoats Grama-Tanglehead/Green Sotol, Pinchot Juniper Phase Black Grama-Sideoats Grama, Pinchot Juniper Phase	
Secondary Components: Curlyleaf Muhly-Sideoats Grama/Texas Sacahuista Curlyleaf Muhly-Sideoats Grama Bullgrass/Texas Sacahuista Black Grama-Blue Grama, Pinchot Juniper Phase	
Inclusions: Sideoats Grama/Texas Sacahuista Sideoats Grama/Lechuguilla-Green Sotol Curlyleaf Muhly/Green Sotol Curlyleaf Muhly/Lechuguilla-Green Sotol	
Distribution: minor Chihuahuan Foothill-Piedmont Desert Grassland map unit. It occurs on piedmont slopes (bajadas) on the west side at elevations around 4,500 ft and occasionally on ridge top summits up to 5,000 ft.	

Figure 15. Black Grama-Blue Grama, Pinchot Juniper Phase Grassland on the south-facing Yucca Canyon bajada below the Guadalupe Escarpment. The elevation is 4,318 ft.
(Photo: Y. Chauvin)

Grama Grasslands with Desert Shrubland	**114**
Tall shrubs >10 and <25%; grasses dominant	
Ha: 260 **Acres:**	640
Primary Components: Blue Grama/Skeletonleaf Goldeneye Black Grama-Blue Grama, Viscid Acacia Phase	
Secondary Components: Sideoats Grama/Lechuguilla-Green Sotol, Viscid Acacia Phase	
Inclusions: Viscid Acacia/Black Grama Viscid Acacia/Blue Grama Hall's Panicgrass-Hairy Tridens	
Distribution: limited Chihuahuan Foothill-Piedmont Desert Grassland map unit that occurs on piedmont slopes (bajadas) below the Guadalupe Escarpment to the western side of the park. Elevations are generally below 4,800 ft.	

Figure 16. Blue Grama/Skeletonleaf Goldeneye Grassland along the upper Yucca Canyon bajada at 4,490 ft.
(Photo: S. Yanoff).

Grama Terrace Grasslands	**112**
Tall shrubs <25%; grasses dominant	
Ha: 117 **Acres:**	290
Primary Components: Blue Grama-Tobosagrass/Catclaw Mimosa Black Grama-Blue Grama	
Secondary Components:	
Inclusions: Catclaw Mimosa/Sideoats Grama	
Distribution: minor Chihuahuan Foothill-Piedmont Desert Grassland map unit that occurs on elevated alluvial terraces of valley bottoms. Elevations are usually below 5,200 ft.	

Figure 17. Black Grama-Blue Grama Grassland on alluvial terrace in Walnut Canyon. (Photo: E. Muldavin)

Tobosa Grasslands	**120**
Tall shrubs <10%; grasses dominant	
Ha: 133 **Acres:**	328
Primary Components: Tobosagrass-Burrograss	
Secondary Components:	
Inclusions: Tarbush/Tobosagrass Honey Mesquite/Tobosagrass	
Distribution: minor Chihuahuan Lowland/Swale Semidesert Grassland map unit that occurs on basin bottom alluvial flats of the Black River drainage at elevations below 4,000 ft.	

Figure 18. Tobosagrass-Burrograss Grassland on an alluvial flat near Whites City at an elevation of 3,661 ft. (Photo: Y Chauvin)

Desert Shrublands

Mariola - Goldeneye Desert Shrubland	**51**
Tall shrubs >25% or dominant over grasses	
Ha: 1,328 **Acres:**	3,282
Primary Components: Mariola-Lechuguilla Mariola-Skeletonleaf Goldeneye Ocotillo-Mariola	
Secondary Components:	
Inclusions: Curlyleaf Muhly/Lechuguilla-Green Sotol Cactus Apple-Lechuguilla Cactus Apple-Ocotillo Ocotillo-Lechuguilla	
Distribution: major Chihuahuan Foothill-Piedmont Desert Scrub map unit that occurs on foothill slopes and ridge top summits along the Guadalupe Escarpment and in interior canyons. It is often found in bands corresponding to horizontal sedimentary rock layers. Elevations range from 3,800 to 6,000 ft.	

Figure 19. Mariola-Skeletonleaf Goldeneye Desert Shrubland along an upper south-facing slope in Walnut Canyon at 4,152 ft. (Photo: E. Muldavin)

Cactus - Ocotillo Desert Succulent Shrubland	**53**
Tall shrubs >25% or dominant over grasses	
Ha: 857 **Acres:**	2,118
Primary Components: Cactus Apple-Lechuguilla Cactus Apple-Ocotillo Ocotillo-Lechuguilla	
Secondary Components: Cactus Apple-Wright Beebrush	
Inclusions: Mariola-Lechuguilla Mariola-Skeletonleaf Goldeneye Viscid Acacia-Lechuguilla	
Distribution: major Chihuahuan Foothill-Piedmont Desert Scrub map unit that occurs on lower foothill slopes and upper piedmonts (bajadas) of southerly aspects along the Guadalupe Escarpment and in interior canyons. Elevations are generally below 5,000 ft.	

Figure 20. Cactus Apple-Ocotillo Shrubland along a south-facing slope in lower Walnut Canyon. The elevation is 3,915 ft. (Photo: E. Muldavin)

Viscid Acacia Desert Shrubland	**40**
Tall shrubs >25% or dominant over grasses	
Ha: 1,011	**Acres:** 2,497
Primary Components: Viscid Acacia/Black Grama Viscid Acacia-Lechuguilla Viscid Acacia-Mariola	
Secondary Components: Viscid Acacia/Blue Grama Viscid Acacia-Pricklyleaf Dogweed	
Inclusions: Mariola-Skeletonleaf Goldeneye Creosotebush-Viscid Acacia/Black Grama Creosotebush/Viscid Acacia/Sparse	
Distribution: major Chihuahuan Foothill-Piedmont Desert Scrub map unit that occurs on lower footslopes and upper piedmonts (bajadas) below the Guadalupe Escarpment and in interior canyons. Elevations range between 3,700 and 4,700 ft.	

Figure 21. Viscid Acacia-Mariola Shrubland along the Yucca Canyon bajada at 4,404 ft. (Photo: S. Yanoff)

Creosote Bush - Viscid Acacia Desert Shrubland	**52**
Tall shrubs >25% or dominant over grasses	
Ha: 440	**Acres:** 1,088
Primary Components: Creosotebush/Sparse Undergrowth Creosotebush-Viscid Acacia/Black Grama Creosotebush/Viscid Acacia/Sparse	
Secondary Components: Creosotebush-Mariola Creosotebush/Sparse Undergrowth	
Inclusions: Viscid Acacia/Black Grama Viscid Acacia-Lechuguilla Viscid Acacia-Mariola	
Distribution: limited Chihuahuan Foothill-Piedmont Desert Scrub map unit that occurs on lower piedmonts (bajadas) and slopes of the Guadalupe Escarpment. Elevations are generally below 4,000 ft.	

Figure 22. Creosotebush-Viscid Acacia/Black Grama Desert Shrubland on a bajada slope near Whites City. Elevation is 3,658 ft. (Photo: A. Browder)

Tarbush - Littleleaf Sumac Desert Shrubland	**42**
Tall shrubs >25% or dominant over grasses	
Ha: 101 **Acres:**	250
Primary Components: Tarbush/Black Grama Tarbush/Tobosagrass	
Secondary Components: Littleleaf Sumac/Sideoats Grama Littleleaf Sumac/Blue Grama	
Inclusions: Tobosagrass-Burrograss Honey Mesquite/Tobosagrass	
Distribution: minor Chihuahuan Basin Desert Scrub map unit that occurs in drainages and on basin bottom flats of the Black River drainage at elevations below 4,000 ft.	

Figure 23. Tarbush/Tobosagrass Desert Shrubland in an arroyo drainage along the eastern Guadalupe Escarpment bajada at 3,630 ft. (Photo: E. Muldavin)

Catclaw Mimosa Desert Shrubland	**41**
Tall shrubs >25% or dominant over grasses	
Ha: 1,328 **Acres:**	3,282
Primary Components: Catclaw Mimosa/Sideoats Grama	
Secondary Components: Blue Grama-Tobosagrass/Catclaw Mimosa	
Inclusions: Black Grama-Sideoats Grama	
Distribution: minor Chihuahuan Foothill-Piedmont Desert Scrub map unit that occurs on lower foothill slopes and on sandstone ridges and benches at elevations from 4,600 to 5,650 ft.	

Figure 24. A Catclaw Mimosa/Sideoats Grama grassland on a sandstone bench below Guadalupe Ridge at 5,650 ft. (Photo credit?)

Arroyo Riparian Woodlands and Shrublands

Arroyo Riparian Woodland	**14**
Trees >25% or dominant	
Ha: 67 **Acres:**	164
Primary Components: Netleaf Hackberry-Little Walnut Little Walnut-Desert Willow/Sideoats Grama	
Secondary Components:	
Inclusions: Texas Mountain Laurel-Roemer Catclaw Green Sotol/Catclaw Mimosa Bigtooth Maple-Chinkapin Oak	
Distribution: minor Southwest Arroyo Riparian Shrubland map unit found at lower elevations (<5,000 ft) along ephemeral washes.	

Figure 25. Netleaf Hackberry-Little Walnut Arroyo Woodland on channel side terrace in lower Walnut Canyon (elevation 3,928 ft). Although limited in distribution, these are critical wildlife habitats in the park.
(Photo: Y. Chauvin)

Canyon - Bajada Arroyo Shrubland	**24**
Tall shrubs >25% or dominant	
Ha: 203 **Acres:**	503
Primary Components: Texas Mountain Laurel-Roemer Catclaw Mexican Buckeye-Texas Mountain Laurel	
Secondary Components: Littleleaf Sumac-Texas Mountain Laurel	
Inclusions: Littleleaf Sumac/Blue Grama	
Distribution: limited Southwest Arroyo Riparian Shrubland map unit found in foothill canyons and inset arroyos of the Guadalupe Escarpment bajada. Elevations usually < 5,000 ft.	

Figure 26. Mexican Buckeye-Texas Mountain Laurel Shrubland in Yucca Canyon at an elevation of 4,728 ft.
(Photo: Y. Chauvin)

Green Sotol - Apache Plume Arroyo Riparian Shrubland	**23**
Tall shrubs >25% or dominant	
Ha: 98 **Acres:**	243
Primary Components: Green Sotol/Catclaw Mimosa Apacheplume/Green Sotol	
Secondary Components:	
Inclusions: Catclaw Mimosa/Sideoats Grama Cactus Apple-Lechuguilla	
Distribution: minor Southwest Arroyo Riparian Shrubland map unit found at lower elevations (<5,000 ft) along ephemeral washes. Green sotol dominated communities are found primarily in the eastern portion of the park, while apache plume communities are mostly in the west.	

Figure 27. Green Sotol/Catclaw Mimosa Arroyo Shrubland on an alluvial terrace in lower Walnut Canyon (elevation 3,916 ft). (Photo: Y. Chauvin)

Desert Willow Arroyo Riparian Shrubland	**20**
Tall shrubs >25% or dominant	
Ha: 121 **Acres:**	30 0
Primary Components: Desert Willow-Texas Mountain Laurel	
Secondary Components: Barren arroyo channel	
Inclusions: Green Sotol/Catclaw Mimosa Apache Plume/Green Sotol	
Distribution: minor Southwest Arroyo Riparian Shrubland map unit found at lower elevations (<4,500 ft) in gravelly arroyo channels.	

Figure 28. Desert Willow-Texas Mountain Laurel Arroyo Shrubland in the gravelly arroyo channel of lower Walnut Canyon. (Photo: E. Muldavin)

Mixed Arroyo Riparian Shrubland	**21**
Tall shrubs >25% or dominant	
Ha: 113 **Acres:**	278
Primary Components: Littleleaf Sumac/Blue Grama Catclaw Mimosa/Sideoats Grama	
Secondary Components: Black Grama-Blue Grama, Cactus Apple Phase Green Sotol/Catclaw Mimosa	
Inclusions: Desert Willow-Texas Mountain Laurel Apache Plume/Green Sotol Barren arroyo channel	
Distribution: minor Southwest Arroyo Riparian Shrubland map unit found at lower elevations (<4,500 ft) on alluvial terraces adjacent to arroyo channels. A complex of various arroyo shrubland communities.	

Figure 29. Littleleaf Sumac/Blue Grama Shrubland on an alluvial terrace in lower Walnut Canyon at 4,080 ft.
(Photo: E. Muldavin)

Mimosa-Acacia Arroyo Riparian Shrubland	**22**
Tall shrubs >25% or dominant	
Ha: 92 **Acres:**	228
Primary Components: Catclaw Acacia/Bullgrass Catclaw Mimosa/Sideoats Grama	
Secondary Components:	
Inclusions: Green Sotol/Catclaw Mimosa Black Grama-Blue Grama, Cactus Apple Phase Littleleaf Sumac/Blue Grama Apache Plume/Green Sotol	
Distribution: minor Southwest Arroyo Riparian Shrubland map unit found at lower elevations (<5,000 ft) on alluvial terraces adjacent to arroyo channels and extending to adjacent footslopes.	

Figure 30. Mimosa/Sideoats Grama Arroyo Shrubland on a alluvial terrace in Slaughter Canyon at 4,668 ft.
(Photo: Y. Chauvin)

Other Miscellaneous Map Units

Herbaceous Wetland	**9**
Shrub cover < 10%	
Ha:	**Acres:**
Primary Components: Western Umbrella-sedge-Sand Spikerush	
Secondary Components: Western Umbrella-sedge-Sand Spikerush	
Inclusions: Rio Grande Cottonwood-Goodding Willow	
Distribution: limited map unit restricted to the wetlands downstream of Rattlesnake Springs, and isolated springs within the interior of the park.	

Figure 31. Western Umbrella-sedge-Sand Spikerush persistent emergent wetland at Longview Spring, elevation 5,771 ft. (Photo: Y. Chauvin)

Forested Wetland	**9**
Trees > 25% or dominant over other strata.	
Ha:	**Acres:**
Primary Components: Rio Grande Cottonwood-Goodding Willow Rio Grande Cottonwood-Netleaf Hackberry-Goodding Willow	
Secondary Components: Rio Grande Cottonwood-Russian Olive	
Inclusions: Netleaf Hackberry-Little Walnut Arroyo Woodland	
Distribution: limited map unit restricted to the wetlands downstream of Rattlesnake Springs.	

Figure 32. The Rio Grande Cottonwood-Goodding Willow Forested Wetland is found only at Rattlesnake Springs. (Photo: E. Muldavin)

Cliff/Rock/Barren/Arroyo Wash	**9**
Perennial vegetation cover < 10%	
Ha: 628 **Acres:**	1,553
Primary Components: Rock outcrop Arroyo channel wash	
Secondary Components: Barren basin alluvial flat	
Inclusions: Ocotillo-Lechuguilla Cactus Apple-Ocotillo Mariola-Skeletonleaf Goldeneye	
Distribution: limited map unit, but one found throughout the park, particularly along horizontal beds of sedimentary rock.	

Figure 33. Cliff face in lower Walnut Canyon. "Hanging gardens" dominated by small succulents and perennial forbs are prevalent among the rock outcrops of the park.
(Photo: E. Muldavin)

Developed Ground/Disturbed	**9**
Perennial vegetation < 1%	
Ha: 90 **Acres:**	222
Primary Components: Roads and paved areas Buildings	
Secondary Components: Barrow pits and other disturbed areas	
Inclusions:	
Distribution: minor map unit associated primarily with park facilities and roads.	

Figure 34. The buildings and structures associated with the main cave entrance occupy the majority of this map unit.
(Photo: Y. Chauvin)

Agriculture/Old Field	**7**	[no photo available]
Natural vegetation < 1%		
Ha: <25 **Acr**	**es:** <75	
Primary Components: Old fields with weedy vegetation Planted/cultivated trees, shrubs and herbs		
Secondary Components:		
Inclusions: roads and buildings		
Distribution: minor map unit associated with old fields at Rattlesnake Springs.		